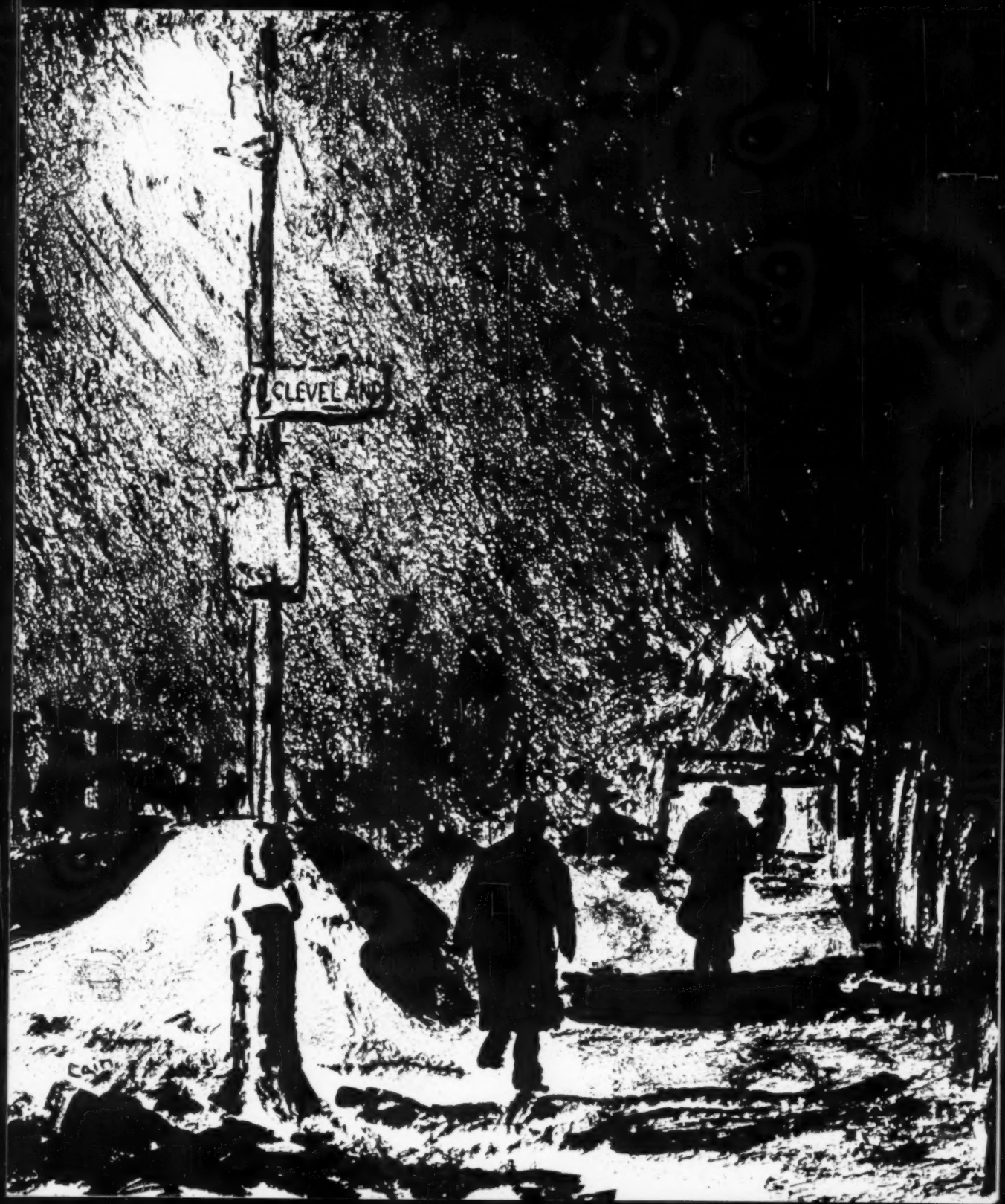
JOURNAL OF

METALS

DECEMBER 1959



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JOURNAL OF

METALS

Vol. 11, No.12
December, 1959

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COVER: David Cain, our cover artist is not a weather prophet! We hope for sunshine, but whatever the weather we're expecting top attendance at the 17th Annual Electric Furnace Conference in Cleveland. This issue contains the conference program and several of the outstanding papers to be presented.

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EDITORIAL STAFF: Editor in Chief, F. Weston Starratt; **Associate Editor,** James J. Burke; **Production Editor,** Otto Johnson; **News Editor,** R. M. Schelkopf; **Editorial Assistant,** C. M. Cardon.
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personnel

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• When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

—MEN AVAILABLE—

All those listed under "Men Available" have membership in the AIME.

Plant Superintendent; B.S. Met. E., age 37. Three years melting and fabricating aluminum; 10 years basic open hearth and electric steelmaking, both in mills and foundry. Experienced in casting and forging of ingots up to 30-ton. Also experienced in research and complaint investigations. Locate anywhere. M-1005-Chicago.

Market Analyst; B.S. Met E. and M.B.A., age 28. Two years experience in metallurgy laboratory of large steel company; one year in metallurgical research; one year in material specifications dept. of well-known auto manufacturer. Presently employed as market analyst for large glass company. Any location. M-219.

Research Engineer; M.E., age 28. Seven years research and development experience in powder metallurgy on filter materials, high-temperature alloys, refractory metals, cermets, ductile metals, and nuclear fuel elements in forging, hot pressing, rolling, slip casting, extrusion, and testing programs. $10,000. Prefer East. M-220.

Metallurgical Engineer; Met E, age 32. Eight years experience as metallurgist supervising engineering and analysis for lead and zinc smelters. Two years experience on analysis and test at flotation mill. $8400. Prefer West. S(M)-488.

Metallurgist; Met E, age 24. One year's experience as process engineer developing and improving new and existing metallurgical practices for electrical furnace manufacturer of ferro and special intermediate alloys. Small-scale pilot work for refractory. One year's experience as engineering trainee in production and development for ferro alloy and calcium carbide manufacturer. $7000. Prefer San Francisco bay area or West. S(M)-1214.

Metallurgist; Met E, age 40. Eleven years supervising personnel; metallurgy in lead smelters; research on casting techniques at cadmium refinery; foreman at copper refinery and aluminum rolling mills. $8400. Prefer Calif. or Northwest. S(M)-927.

Superintendent; Met E, age 32. Six and one-half years experience as head of department (gold, silver refinery, sheet lead, and casting), lab assay, safety, personnel, design, labor-management contracts. For smelting and refining company. $10,000. Prefer San Francisco bay area. S(M)-583.

Sales Engineer; Mine, Met E, age 45. Extensive experience on field work, lab, design, operation of flotation, gravity, chemical plants; sales engineering and management. $9600 up. Prefer West or foreign. S(M)-802.

Designer, Superintendent; M.E. (Scotland), age 45. Twenty-three years in charge of sales, engineering, design, contracts, estimates for steel mill construction, furnaces, cranes. Two and one-half years experience as industrial engineer doing methods, time study design of plant and tools for box manufacturer. One and one-half years experience in civil, mechanical, and electrical maintenance for bronze casting and forgings plant. $15,000. Prefer West coast. S(M)-1629.

Mill Foreman; Min E, age 46. Two years experience as mill shift foreman doing crushing, grinding, classification flotation, concentration, and cyanidation of lead, silver, and zinc ores. Eight months as asst. mine supt. in development exploration on underground and surface. Three and one-half years in assay, mill, as mine shift boss in silver, gold, copper mines. $7200. Prefer Calif. S(M)-463.

Metallurgist; Met E, age 41. Two years as consulting mining and metallurgical engineer on nonferrous minerals in heavy aggregate field doing examination, reports, studies. Seven years experience in construc-

(Continued on page 776)

RESEARCH METALLURGIST is sought as group leader. Advanced degree required or record of technical achievement. Several years of industrial experience necessary, preferably in ferrous metallurgy. The job requires planning of research programs directed toward the use of lithium and manganese in metallurgical applications; phase diagram studies; physical and mechanical properties of alloy systems; chemical properties of alloys. Salary open. Location East.

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METALLURGISTS, Graduate metallurgists with up to three years experience. To work in the quality control laboratories of a well-known aircraft and commercial forging company. Materials range from light metals including titanium through high temperature and refractory metals. Diversified physical metallurgical problems including development work on the effect of forging variables and heat treatments on room temperature and elevated temperature properties of various alloys. Location, New England.

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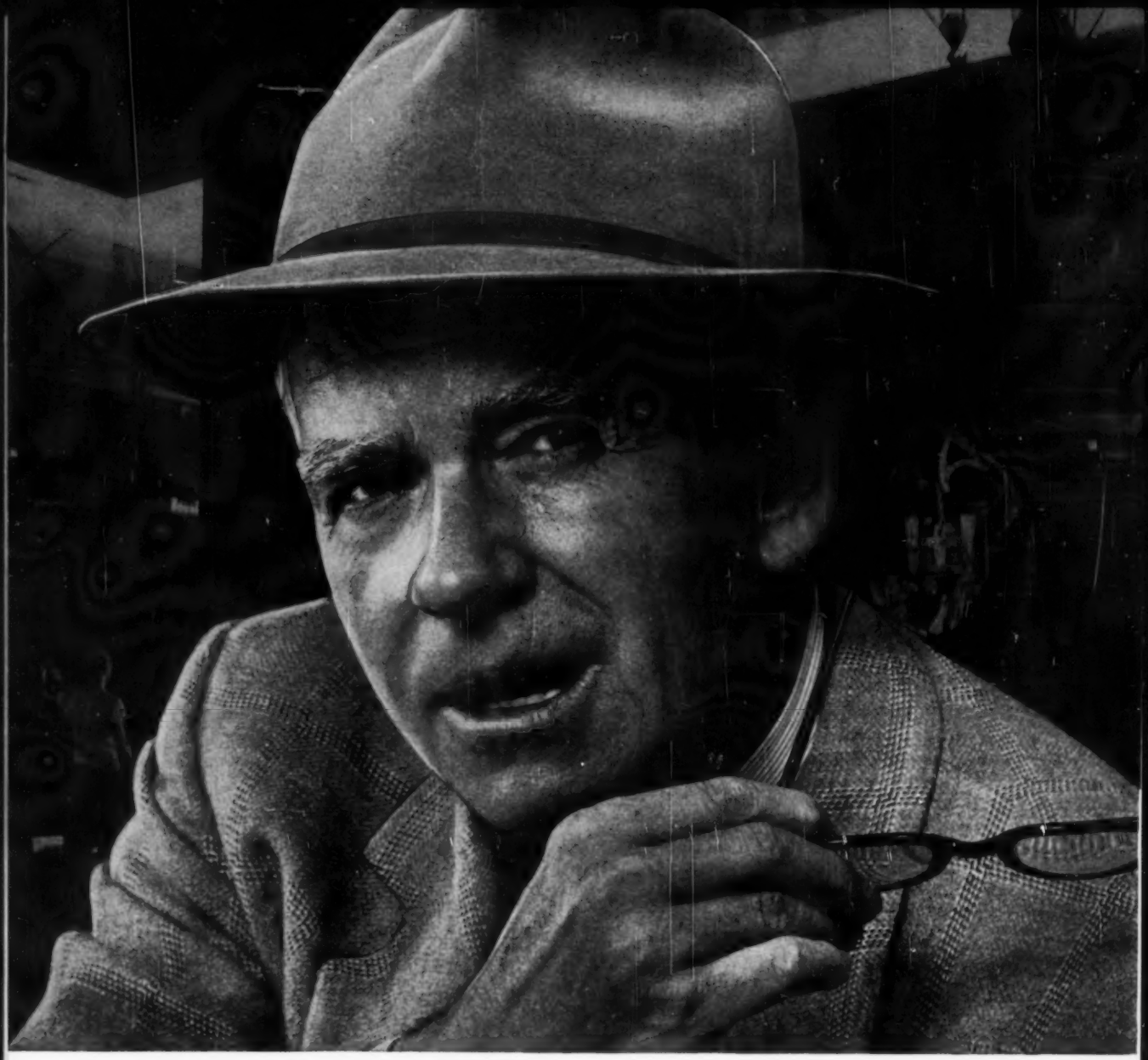

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PERSONNEL

(Continued from page 774)

tion of plant, ore dressing operation for uranium, lead, copper smelters. Also development of mining beneficiation of phosphate rock, process changes on titanium in chemical and reduction plants. One and one-half years experience as plant supt. over production, materials handling, equipment for gypsum processor. $15,000. Prefer West or Northwest. S(M)-207.

Research Engineer; Phys Chem, age 33. Two and one-half years in research development, material analysis, adaptation of manufacturing procedures for new alloys and refractory metals for aircraft companies. Two and one-half years as physical metallurgist in research and evaluation of ordnance development; six and one-half years as asst. supt. metallurgist for basic steel manufacturing. $8400. Any location. S (M)-342.

Superintendent; Min E, age 55. Thirty years experience planning and supervising production, mine examination, exploration and development programs in mining, metallurgy, and petroleum. $8400. Prefer US. S(M)-221.

Metallurgist; ChE (Canada), age 47. Seven years as manager responsible for quality of metallurgical engineering for consultants and designers; 20 years as director of research for mine, mill, and smelter. $15,000. Prefer West. S (M)-104

—POSITIONS OPEN—

Metallurgist; B.S. in metallurgy with at least five years supervisory experience in high-alloy (nickel, chromium, iron) foundry. Location: Midwest. W8082.

Engineers. a) Metallurgist; B.S. or M.S. in metallurgy or metallurgical engineering with three to five years experience in laboratory analysis of all types of materials, including knowledge of chemical tests required to evaluate chemical properties of such materials. To $10,000. Location: Ky. W8074(a).

Chemical Engineer. B.S. in Chem E, with experience in plant design, construction, operating, and technical service in ore processing for metallurgical and chemical fields. $7500 to $9000. Location: New England. W8013.

Met E or M.E. for design and development of small threaded metallic fasteners in aviation products. Salary, to $6600. Location: Midwest. W8008(a)

Metallurgist; graduate with ferrous production experience. Responsibilities include organization of technical classes and supervision of metallurgical education program, but will not include teaching. Some travel required. This is an administrative staff opening. Location: Pa. W7481.

Metallurgical Engineer with degree and six to 10 years experience in metal forming, stress relieving, and all types of welding desired. Emphasis on automatic submerged arc, automatic and manual inert gas, manual metal arc, and gas welding. $9600 to $13400. Company will pay fee. Location: Tenn. C7727(a).

Consulting Engineer; metallurgist with wide experience in copper smelting and refining and familiar with operations and engineering in various copper producing areas of the world. Will provide technical direction for metallurgical plant design and construction, technical assistance to operating smelters and refineries. Will also handle development work for new methods. Must be top-notch with broad experience. Some travel. Salary open. Location West. W7906.

Sales Engineer in powder metallurgy, preferably with technical and production experience. Sales experience valuable but not necessary. Contacts are in all phases of iron, associated metal powders, and vacuum metallurgy. Location: Midwest. W-7902.

Sales Engineer with three to five years metallurgical development and marketing experience. To plan and execute market research and development, perform application and technical service duties in alloy wire fields. Considerable travel. $10,000 to $12,000. Company will pay placement fee. Location: Pa. W7884.

Welding Engineer with metallurgical degree and minimum of seven years production welding experience, preferably in nonferrous metals. Must be acquainted with X-ray techniques, familiar with aircraft or equivalent quality requirements. Will have complete responsibility for production welding program from technical aspects, i.e., selection of equipment, application of techniques, joint design, establishment of procedures, and so on. Salary open. Location: Pa. W7867.

Sales Vice President; metallurgy or mechanical engineering graduate with considerable sales management and sales promotion experience in nonferrous metals and fabricated products. $35,000, plus bonus. Location: East. W7803.

Metallurgists to promote the use of ferro alloys and metals produced, and to assist in the development of new products. a) Metallurgist, graduate with five or more years experience in the nonferrous field, chiefly in the production and processing of wrought and cast aluminum alloys. Some practical knowledge of metals like copper and titanium is desirable. b) Metallurgist with good background of steel production, primarily melting and processing of unalloyed and low-alloy open hearth and electric furnace tonnage steels. Should have good experience in established practices, including application of ferro alloys, refining agents, quality control, and inspection procedures. Salaries open. Location: Midwest. W7488.

Research Metallurgist; B.S. in physical chemistry or metallurgy; M.S. or Ph.D. in metallurgy desirable. Interest in research essential

(Continued on page 778)

wanted . . .

technical editor

A metallurgist who would rather write than metallurg . . . someone who can write and who has a good background in engineering . . . in short an editor for a metals magazine. Write immediately to Box 17-JM, AIME, 29 West 39th Street, N.Y., N.Y.

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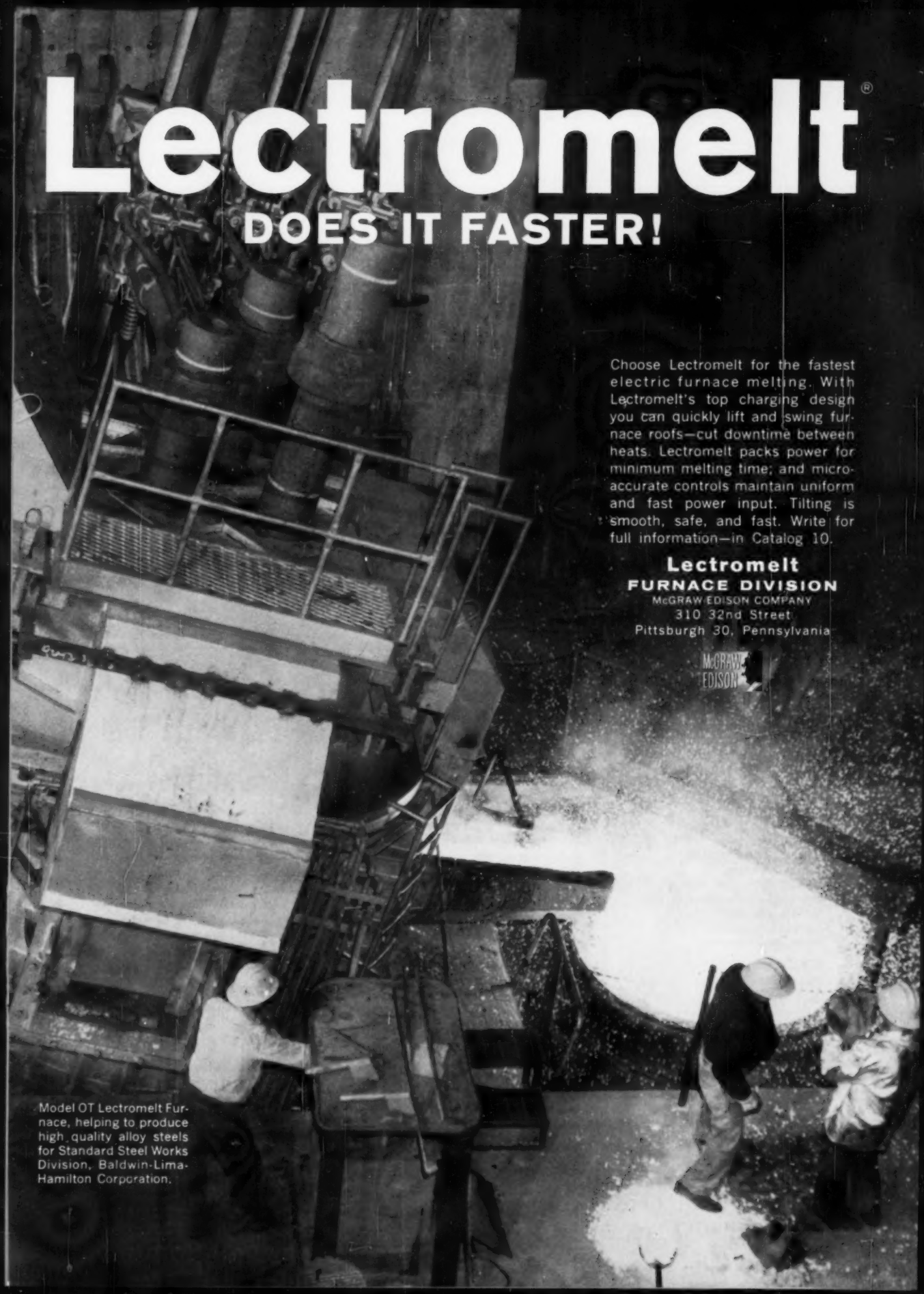

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PERSONNEL

(Continued from page 776)

for conduct of developmental projects and investigations in physical metallurgy. Only occasional supervisory direction as to program or procedure. $8000 to $11,000. Company will negotiate fee. Location: Pa. W8090.

Metallurgist; graduate in metallurgy or chemical engineering experienced in or aptitude for lead smelting for development, research, and operation. $6000 or more. Location: Midwest. S(P)-4785-R.

Welding Engineer; graduate exceptionally well qualified in automatic machinery, welding, and have complete knowledge of machinery, practice, and equipment as applied to steel, aluminum, titanium, magnesium, and a great variety of metals. Must be able to determine and set up appropriate welding procedure, issue instruction to production personnel, and advise plant engineer in maintaining equipment. For manufacturer. US citizenship required. $9000 to $12000. Location: San Francisco peninsula. S(P)-4695.

Research Engineer; B.S., M.S., or Ph.D. in metallurgical or mechanical engineering. Requires minimum of six years metal processing (press working, spinning, machining, chemical milling, and so on) on high-strength steels, titanium, and refractories. Some experience in research and development of metal fabricating processes and techniques is desirable. $9000 to $15,000. Location: N. Calif. S(P)-4690a.

Welding Research Engineers with B.S., M.S., or Ph.D. in metallurgical or mechanical engineering. Requires minimum of six years experience in welding and/or brazing high-strength steels and refractories. Some research and development of metal joining processes and techniques desirable. $9000 to $15,000. Location: N. Calif. S(P)-4690b.

Metallurgical Engineers; B.S., M.S., or Ph.D. in metallurgy or engineering for metal processing and joining of high-strength steels, titanium, and refractories. $9000 to $15,000. Location: N. Calif. S(P)-4690c.

Estimator; graduate in metallurgical, mining, or mechanical engineering. Should have broad experience in heavy industrial construction and engineering estimating, preferably in mining and mineral indus-

(Continued on page 780)

Additional classified advertising appears on pp. 854, 856.

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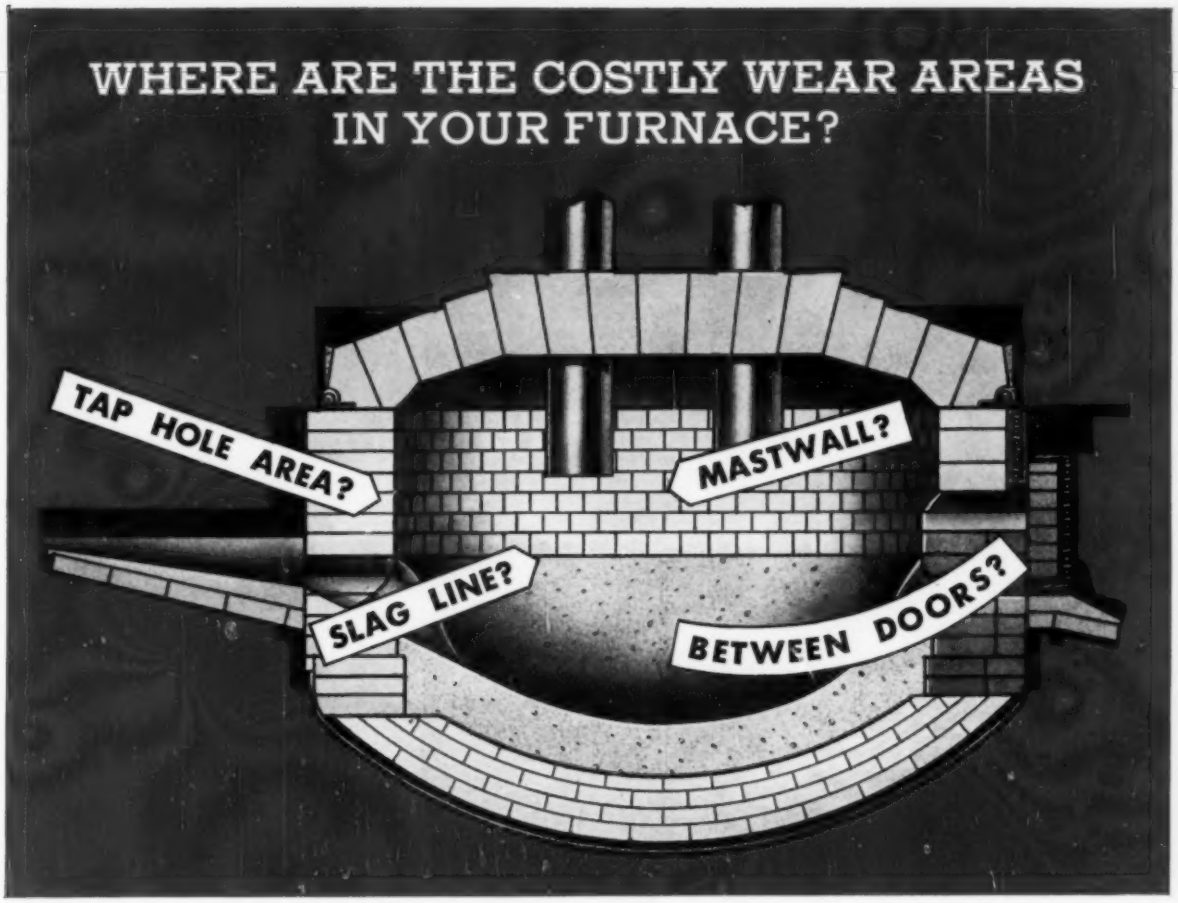

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PERSONNEL

(Continued from page 778)

tries. Must be qualified to make cost estimates on projects, budgetary and appropriation estimates, and supervise small group. Salary and benefits. Location: West. S(P)-4627c.

Metallurgy Consultant; graduate metallurgist. Must have wide experience in copper smelting and refining, and be familiar with operations and engineering in copper-producting areas throughout the world. To provide technical direction for metallurgical plant and design construction. Also technical assistance to operate smelters and refineries, and handle development work for new methods. Must be top-notch, with sound economic sense, and be capable of contact work under variety of circumstances, including top management. Salary commensurate with experience Headquarters: Mountain States. S(P)-4660.

personals

David W. Morgan is now doing graduate work in the School of Mineral Engineering, University of Washington. He was formerly associated with Kaiser Aluminum & Chemical Corp., Permanente, Calif.

David S. Malyevac is now fulfilling his military obligation, following graduation from Montana School of Mines. He is project engineer and firing officer with the US Naval Weapons Laboratory, Dahlgren, Va.

John R. Dunning, dean of the School of Engineering, Columbia University, is a member of a committee appointed to "guide the destinies" of the annual Nuclear Congresses. The 1960 Nuclear Congress will be held Apr. 3-8 at the Coliseum in New York City.

Irving B. Cadoff, New York University, and **Adrian Gammill,** Michigan Chemical Co., were among lecturers in a series on New Materials for Advanced Applications, sponsored by the American Society for Metals. Mr. Cadoff spoke on the *Effect of Radiation on Materials,* while Dr. Gammill talked on *Rare Earth Metals and Compounds.*

Robert G. Page has been elected to the Board of Directors of the Chrysler Corp. Mr. Page is president of the Phelps Dodge Corp.

John G. McMullin is now in charge of the Constructional Alloy Steels Research section of Crucible Steel Co.'s Central Research Laboratory. Dr. McMullin was formerly supv. of

(Continued on page 784)

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In accordance with the best practice for the particular purpose, Harbison-Walker monolith-forming refractories are installed by various methods —such as pouring or tamping, troweling or gun-placement—depending upon the product and its application. For many purposes, they are used for complete linings free of joints, for maintenance in making both small and very large patches. Special shapes for emergency or prompt needs can be fabricated for immediate use.

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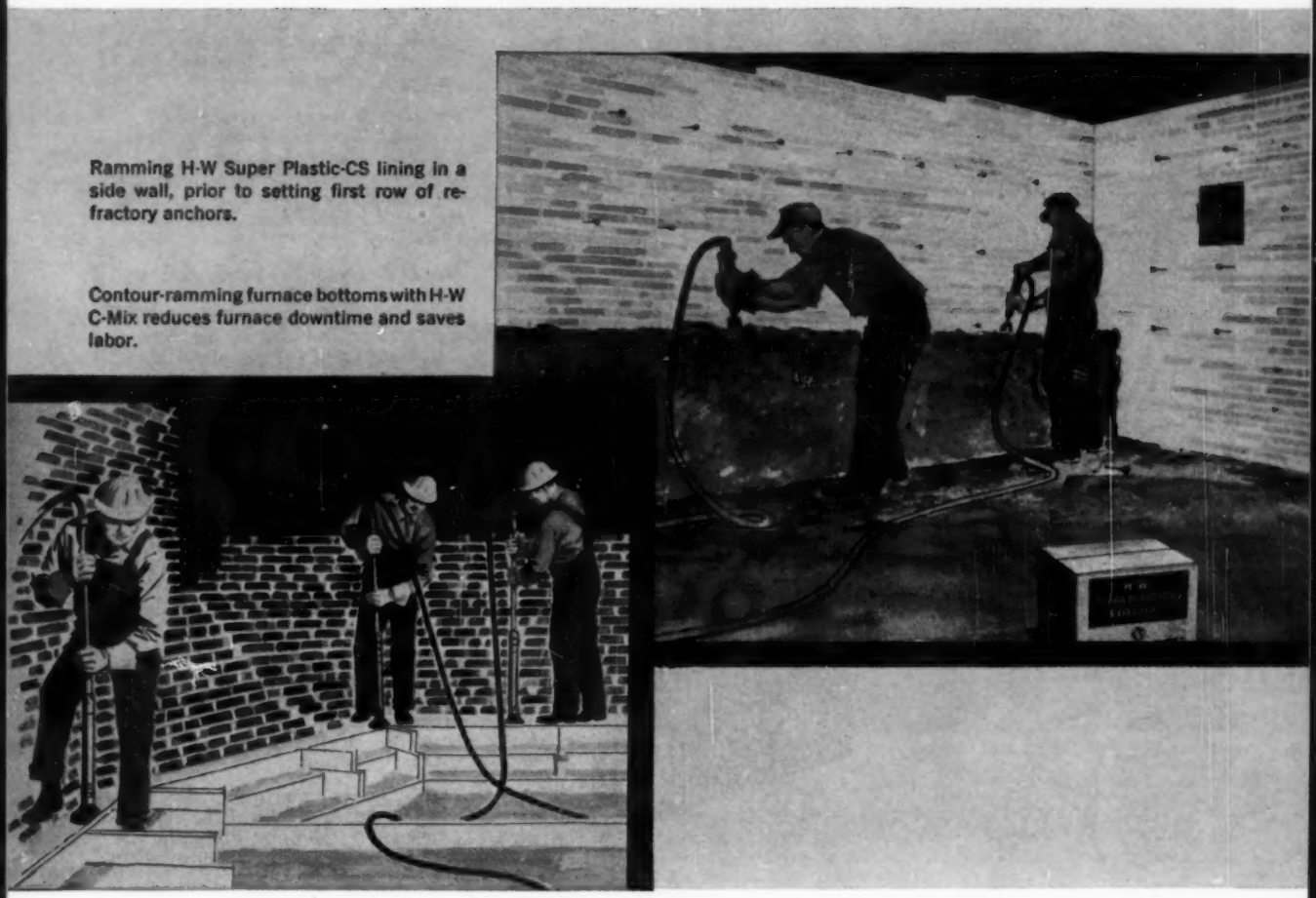
The use of **H-W EXTRA STRENGTH CASTABLE** is highly successful in multiple hearth roasters, fluidized solids reactors and subbottoms of invert arches in various refining furnaces.

CHROMEPAK, the highly basic castable having great resistance to erosion, is proving its good serviceability in charge-hole positions of reverberatory copper smelting furnaces. In a specific modification, it holds particular promise of serving for tuyere patching and for center sections of electric furnace roofs which otherwise involve costly cutting and fitting of brick shapes.

forming refractories

...for metallurgical furnaces



Ramming H-W Super Plastic-CS lining in a side wall, prior to setting first row of refractory anchors.

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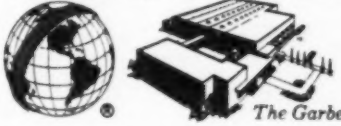

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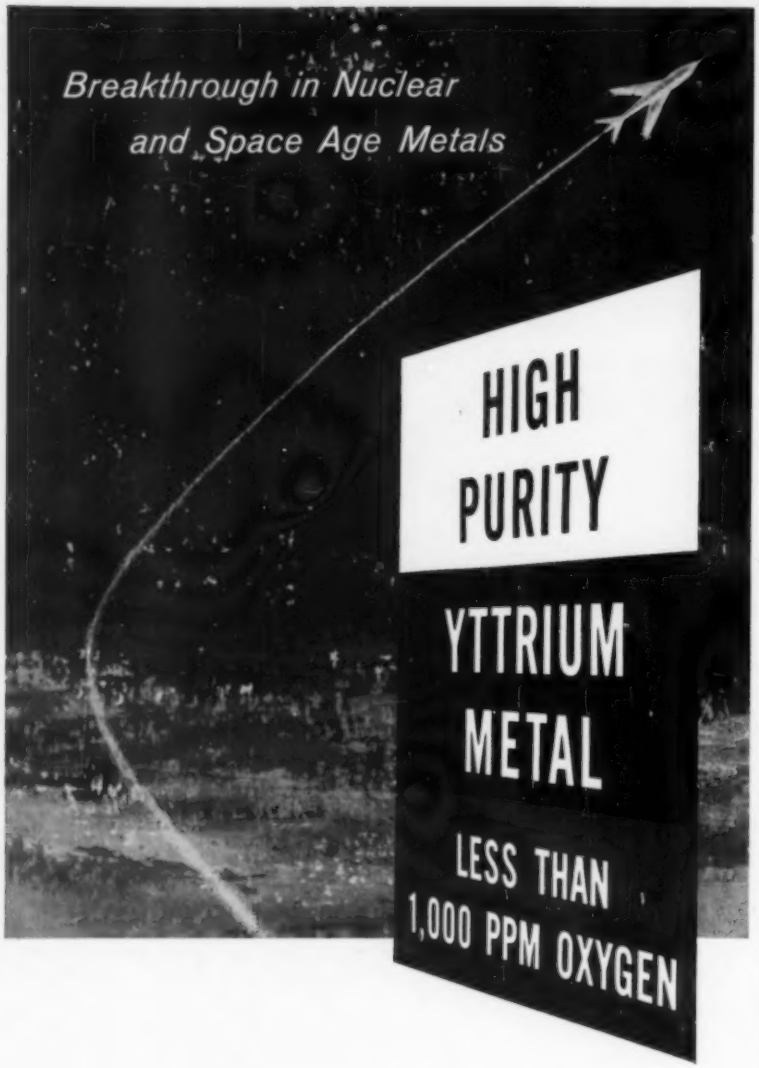

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PERSONALS

(Continued from page 780)

Metallurgy Applied Research in General Electric Co.'s Steam Turbine dept.

Michael Zetz is now plant manager of the Louisville, Ohio, plant of Jones & Laughlin Steel Corp., Stainless and Strip div. Mr. Zetz was formerly supt. of Quality and Production Control at the plant.

Stuart W. Lyman described the role of metallurgical research in space age alloys at an American Institute of Chemical Engineers' symposium Sept. 28th. The missile construction symposium was held in St. Paul, Minn.

Frank Holden, Fred Schwarzberg, and **Robert I. Jaffee** of the Battelle Memorial Institute participated in the October meeting of the American Society for Testing Materials in San Francisco. The trio reported on investigations into *High Temperature Mechanical Properties of Tantalum.* Messrs. Holden and Jaffee were also members of a team reporting on tensile properties of platinum-group metals. **Bruce Gonser,** another Battelle worker, was technical chairman of a meeting on refractory metals' properties, while Mr. Jaffee chairmaned a light metals symposium.

Paul Frost, also a Battellite, was among the contributors to New York University's conference on welding, fabrication, heat-treatment, and alloying of titanium in September. His paper dealt with the cold fabrication of titanium.

Fred Shober has been appointed asst. consultant to the Reactor Metallurgy div., Battelle Memorial Institute. Mr. Shober was formerly a research engineer there.

Cabell B. Finch and **Robin O. Williams** have joined the staff at Oak Ridge National Laboratory, installation of the Union Carbide Nuclear Co., div. of Union Carbide Corp. Mr. Finch is a recent Yale University graduate, while Mr. Williams was formerly with the Cincinnati Milling Machine Co.

Arthur J. Weinig, Jr., will supervise design and process development activities at U.S. Borax & Chemical Corp.'s potash operations, Carlsbad, N. Mex. Mr. Weinig was formerly general manager of the New Mexico Thorium Corp.

E. K. Leavenworth has been appointed a vice president of the Climax Molybdenum Co. of Michigan. He will remain at the Co.'s Coldwater, Mich., plant where he serves as works manager.

Vernon Griffiths is the new head of

(Continued on page 850)

NOW INDUCTION MELTING COSTS LESS THAN EVER...

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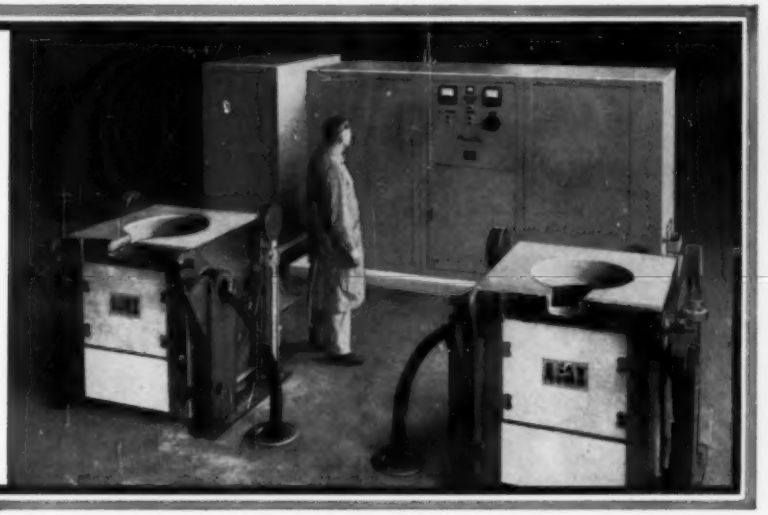

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* LESS INITIAL COST—The initial cost of a typical Multiductor is less than conventional motor generator type equipment. Further, because the unit is shipped completely assembled and wired, installation costs are drastically reduced. Multiductor requires minimum floor space and uses standard 3-phase, 60-cycle power from ordinary sources.

* LESS OPERATING COST—Operation is so nearly automatic that inexperienced hands quickly become expert operators. Output can be varied continuously . . . while under load . . . from zero to maximum with easy-to-use controls. Damage by overload is practically impossible.

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* LESS MATERIAL COST—The strong electromagnetic stirring action of Multiductor powered furnaces promotes rapid melting and diffusion of alloying elements with extremely low metal loss . . . is ideally suited for melting low cost scrap such as borings, turnings, and chips.

* SEE A DEMONSTRATION—Discover for yourself why more and more foundries—at least an additional one each week—are finding that Multiductor Powered Induction Furnaces are one of the greatest melting economizers in history . . . on small furnaces as well as 10-ton units. Write Ajax Electrothermic for a demonstration or an engineer's visit without obligation. Data bulletins are also available.

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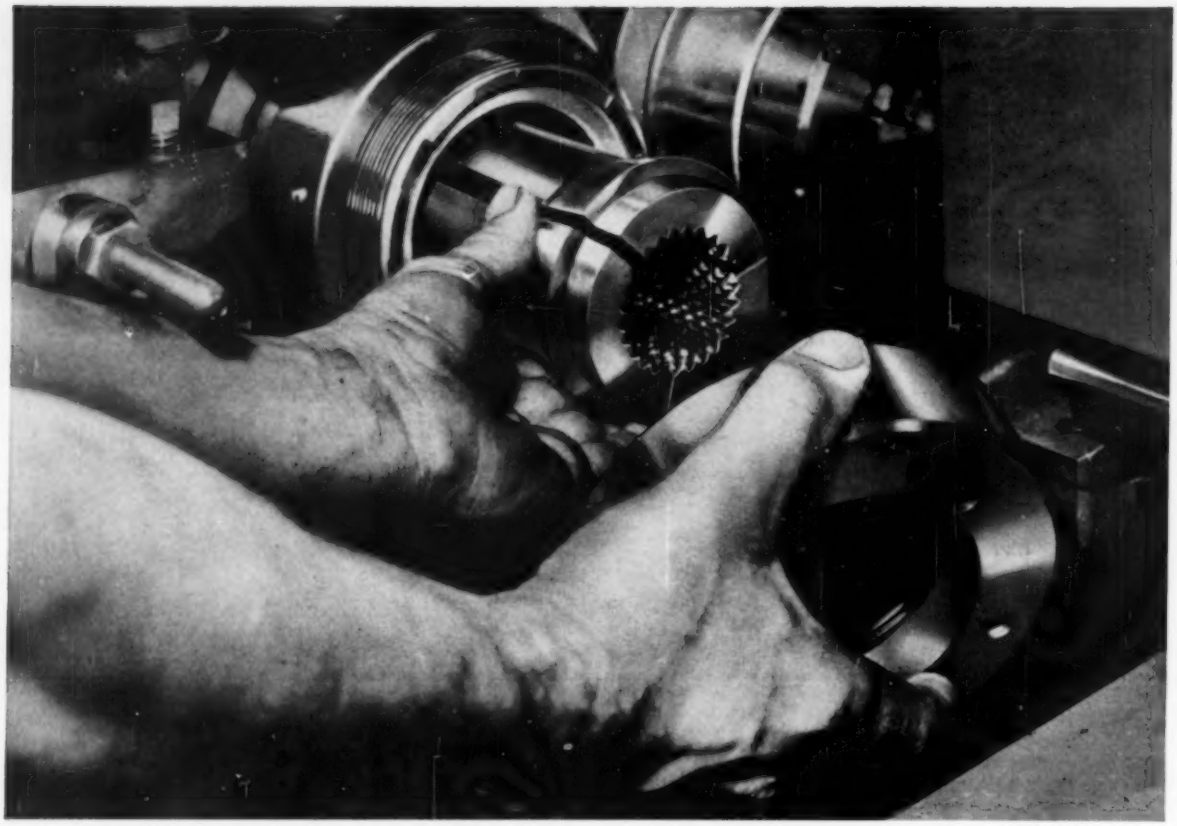

Inspecting 4615 nickel alloy steel spindle in Greenlee 6-Spindle 2" Automatic Bar Machine assembled with collet and 4615 steel spindle nose nut. Greenlee Bros. & Co., Rockford, Ill., also produces 1" and 1⅝" bar machines.

How Greenlee uses two general purpose nickel alloy steels to keep precision machines precise

1...case-hardening 4615 for wearing parts 2...through-hardening 4340 for stressed parts

Do you know that by varying heat treatment of just two nickel alloy steels — 4615 for case-hardening, 4340 for through-hardening — you can give desired hardness and strength to most heavy-duty machine tool parts?

For proof — consider the Greenlee 2-inch automatic bar machine above.

Each spindle is 4615 steel, carburized and hardened to Rockwell C 62-64. The hard case holds down wear or loss of running accuracy, even though spindles turn directly on 5 speed ball bearings. High speed torsional stresses are taken in stride by the tough, strong core. The low distortion characteristics of 4615 steel during heat treatment help to keep true-running accuracy.

4615 steel also gives the same excellent wearing qualities in spindle nose nuts, idler gears, bushings and sleeves.

4340 steel strengthens highly stressed parts

Through-hardening 4340 nickel alloy steel is the off-the-shelf steel Greenlee uses for heavily stressed parts — for example, certain shafts heat treated up to 225,000 psi tensile strength.

Stocked in Steel Service Centers across the country

Versatile 4615 and 4340 nickel alloy steels are available for quick delivery from Steel Service Centers throughout the country . . . ask us for a list of centers where you can buy them. Write us, too, for specific questions concerning these two steels.

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Make diffusion-bond

Marathon Specialty Steels, Inc., New York, reports that its German parent firm, Deutsche Edelstahlwerke, has developed a special line of steels, termed "IK", that are particularly amenable to chromium diffusion. Chromium deposition may be accomplished from a halide vapor at about 1830°F in a closed retort, and results in a diffusion-bonded chromium layer that readily withstands mechanical deformation. The standard depth of the corrosion-resistant surface zone is about 0.004 in.

Report Soviet tin plant

Opening of a Soviet tin producer north of the Arctic Circle, has been reported in the Russian press. Iultin in northeastern Siberia, at a latitude of 68° N. is the site of the plant.

The Iultin operation is said to reduce tin ore into concentrates. The concentrates are then trucked 120 mi to the port of Egvekinot at Krest Bay on the Bering Sea. From there they go to the country's only smelter at Novosibirsk.

Disclosure of the new concentrating plant came in a report of the Soviet Union's 1958 tin production. Exports amounted to 22,300 metric tons, it is said; while imports, almost exclusively from Communist China, were 19,400 tons.

There is an even colder tin producing area than Iultin in the Soviet Union. Verkhoyansk, where the January temperature average is 60° below zero, incorporates a mine and concentrator installation. In 1957 the Verkhoyansk area produced 20 pct the USSR's tin.

The Maritime Province north of Vladivostok still remains the most important tin-producing area in the Soviet Union, having produced since prior to World War II, with new mining operations brought in since then. Nearly all Soviet tin reserves are in lode deposits. Placer ore mixed with gravel accounts for only 9 pct of present reserves.

W-Mo ore separation eased

A method has been developed for the easy separation of tungsten from molybdenum in the production of commercial-grade tungsten and molybdenum powders. The new procedure is known as fused-salt-bath electrolysis. It has been successfully tested on tungsten mineral sheelite, which usually contains the molybdenum mineral powellite as an impurity. Metallurgists at the Reno, Nev., U. S. Bureau of Mines laboratories have produced 98 pct pure Mo and 99 + purity W with the one-step operation. J. B. Zadra heads the research team.

Hi-pressure blast furnace made

A blast furnace with a top pressure of 40 psig—nearly four times that of any existing American blast furnace—has been developed by the Engineering and Construction div. of Koppers Co., Inc. Division vice president and general manager Walter C. Rueckel made the announcement.

Dr. Rueckel estimates that the new blast furnace will produce twice as much pig iron as a furnace of comparable size operated at the usual top pressure. To achieve such results necessitates a completely new furnace rather than adding high-pressure equipment to an existing furnace, Dr. Rueckel explains. It means an additional capital outlay of 20 to 25 pct, but represents a 30 to 35 pct reduction in labor costs required to produce a ton of pig iron.

Owen R. Rice, special consultant at Koppers, headed the team of engineers who worked out the new furnace design. He points out that it differs from conventional furnaces in these respects:

1) The furnace, hot blast stoves, and other parts must be constructed as pressure vessels;

2) The high-pressure gas system must be sealed against leakage;

3) Capacity of blowing facilities is greatly expanded;

4) The high-pressure furnace does not use the conventional blast-furnace charging system, and it eliminates the traditional large bell;

5) High gas pressure does away with electrical precipitators for gas cleaning; and

6) Doubled pig iron output requires doubled cast house facilities, including two tap holes, two mud guns, and duplicate runner systems.

Steel cast in argon

An argon casting technique which eliminates inclusions caused by oxidation during teeming has been announced by the Linde Co., div. of Union Carbide Corp. There are two phases to the process: first, the mold air atmosphere is replaced with argon; then, the molten metal teeming stream is shrouded with a curtain of argon. Inclusion occurrence in aircraft-quality steel has been reduced by 43 pct during tests, and grinding losses on primary conditioning reduced by 9 pct.

Plan S. Rhodesia nickel plant

Plans to build a nickel smelting and refining plant at Bindura, Southern Rhodesia, have been announced by Shimura Kako Chemical Processing of Japan. The South African company of Anglo Vaal Ltd. is co-partner in the venture, being half-owner of the Bindura nickel mine. The facility, designed to produce nickel matte for shipment to Japan for electro refining, will involve an expenditure of some $3 million. The mine, called the Trojan, is said to have a 40 million ton resource of nickel ore.

REPORTER

REPORTER

Dunkerque, Rotterdam steel seen

The trend toward construction of coastal steel plants is increasing as steel becomes more and more dependent upon raw materials imported from far-flung global points. Since World War II, major coastal steel plants have been constructed in the UK, Italy, and Germany. Today, plans are being made for two additional large-scale integrated steel works . . . one at Dunkerque on the northern French coast . . . the other at the Dutch port, Rotterdam.

Société Dunkerquoise, set up by Usinor and two other French steelmaking firms, has 1000 acres bordering on the port at its disposal. It is estimated that, upon completion of port improvements, a 35,000-ton ore carrier will be able to unload in 10 hr. Production of the first phase of the operation is slated for 1962. Plates, which find a ready market in the area, are expected to be its first product.

An initial output of 500,000 metric tons of pig iron a year is exepcted using a single blast furnace of 8.5-m diam charged with 100 pct sinter burden. The pig iron will be processed in two open hearths or two 100-ton LD converters, using lime powder injection in a jet of oxygen. After reheating, the ingots will be rolled in a slabbing mill, then go to a four-high plate mill which will produce plates up to 3.5 m wide and 5 mm thick. Coke for the furnaces will come from nearby collieries, while ore will be shipped from overseas, particularly Mauretania.

Meanwhile, the Netherlands is planning an iron and steel plant at the mouth of the Maas River below Rotterdam . . . longtime intermediary for ore shipments from ocean-going vessels to Rhine barges. With the development of the Labrador ore fields for use by European mills and the inability to ship ore from these mines during Winter months, it has become necessary to carry substantial ore stocks at some intermediate points. Thus, the Hanna Mining Co. of Cleveland and a firm of ore merchants in Rotterdam have just completed a stockage area for upwards of 1.5 million tons of ore near the proposed steel mill. At the same time, the city of Rotterdam is actively engaged in a project for a European port which includes additional ore stockage facilities. This area, thus, seems ideal for the development of a steel industry.

The project, as proposed, calls for a number of stages, the first providing a pig-iron capacity of 375,000 tons annually and a rolled steel capacity of 350,000 tons. When all stages are completed the mill's capacity will be about 3 million tons a year.

A capital outlay of $90 million will be needed to finance the first stage alone. Wire rod and other products will probably make up the first results of the steelmaking plant. Plans for the new installation lead Dutch authorities to predict that the country's steel production may reach 5 million tons annually in the near future.

Chromium extrusion produced

The first successful extrusion of pure chromium metal tubing has been accomplished by James Wong of Nuclear Metals, Inc., div. of Union Carbide Corp. Dr. Wong made the extrusion by cold compacting laboratory-grade chromium powder into a mild steel container; it is then heated, placed in a 1000-ton press, and extruded over a mandrel. The resultant tubing had a theoretical density approaching that of chromium. Further development will be necessary to realize a practical method of producing ductile chromium in usable quantities. Ductile chromium tubing could solve the problem of containing hot exhaust and propulsion gases of rocket nozzles and jet tubes.

Indian steel capacity upped

A steel production target of 10 million tons has tentatively been approved for India's third five-year plan, to begin in March 1961. Coal output will probably be set at 110 million tons. Plants at Bhilai, Durgapur, and Rourkela are all to be expanded, and a fourth plant is to be established at Bokaro. A fifth plant to be located in southern India has also been hinted. Capacity of the Bhilai plant, built with the help of the USSR, is expected to double to 2 million ingot tons by 1966. The German engineered Roukela plant will expand from 0.8 to 1.8 million tons. The British-sponsored Durgapur plant is set to grow from 0.6 to 1.6 million tons. Russia has already extended considerable credit to India toward the third five-year plan. West German and British credits are also expected.

In other news from India, it is learned that the Bhilai steel work's first open hearth was commissioned on Oct. 12th. The USSR-planned plant, thus, has the largest furnace in India, with a capacity of 250 tons. Two more furnaces are due for completion within the next three months, with three more scheduled for operation next year. In Rourkela, meanwhile, completion of a second blast furnace has been announced. For the complete story of India's steel future, see p. 734 of the November issue.

Make 99+ pure Cr

A 99.99+ pct pure crystal bar of chromium has been prepared by Battelle Memorial Institute researchers. Developed by a process involving thermal decomposition of chromium iodide, the bar form of chromium holds prospects for the development of space-age metals. Because of its purity, the metal will enhance the fabricability and ingot yield of present wrought commercial chromium-containing alloys. The metal, called *Iochrome*, is also expected to be useful in obtaining ductile chromium-base alloys.

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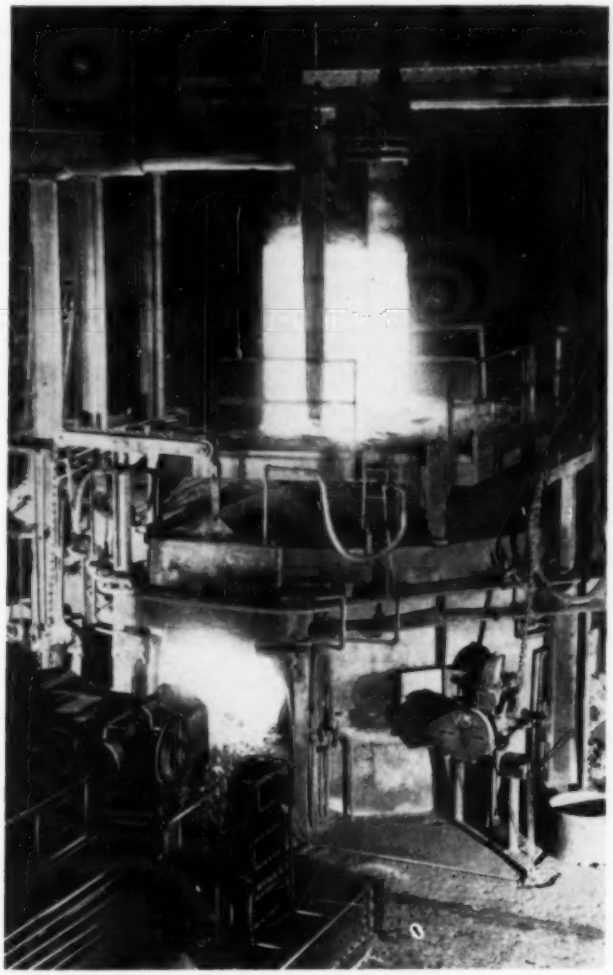

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letters to the editor

In Err

Please refer to the following paper published in the August 1959 JOURNAL OF METALS: *Electrolytic Copper Refining at High Current Densities*, by S. J. Wallden, S. T. Henriksson, P. G. Arbstedt, and Th. Miöen.

Under the paragraph headed "Experiments with channel electrolyzers," the following statement is made: ". . . However, it should be mentioned, at this point, that this idea of a suitable cell for electrolysis at high current densities has been published earlier in two U.S. patents.". . ." Our reference No. 6 to these patents reads: "U. S. Patent 1,456,994 and 2,196,335."

However, these numbers are wrong and we are so sorry we did not observe the mistakes in our manuscript. Would you be so kind to correct these U.S. patent numbers in your journal. The right numbers are U.S. 1,466,994 and 2,196,355.

We regret having to bother you with this and thank you in advance.

Ragnhild Johnsson
Bolidens Gruvaktiebolag
Skelleftehamn, Sweden

Factual Advertising

The following letter came in response to a marketing survey sent to members of The Metallurgical Society.

The influence exerted by AIME members in the procurement of purchased products and services is greatly underestimated by the vendors of such goods and services. This is evidenced by the small volume and shortage of specific factual-type advertising appearing in the JOURNAL OF METALS. The basic decision on what to buy in big industry is vested in technical people. The choice of a vendor and issuance of a purchase order is the function of a procurement department.

The purchase requisition, which authorizes a purchase order, originates from a technical man who must have all the physical, chemical, mechanical, and economic facts to enable him to determine that the item will do the intended job within the associated systems and budget of the project. Often there is no time to call in salesmen or write for additional information and prices. In arriving at his recommendations, the logical inclination of the technical man is to favor that product about which he has the necessary information to accept in his own mind, and to sell it to higher management for final decision.

Justification for single source procurement must be based on unique characteristics in contrast to similar properties of all competitive products, and must be backed with specific figures.

Members of The Metallurgical Society of AIME may have job titles other than metallurgist, such as designer, design specialist, standards engineer, materials engineer, manufacturing engineer, tool engineer, and the like. It is their job to fit the product to the purpose. Time limitations preclude wading through all the ads of the trade journals and writing for information. Their preference is to find complete and concise facts in their own technical society journals. It is to be hoped that some day the vendors will discover this, and then, perhaps, the technical men will escape the continual frustration of being unable to use new products because of insufficient information.

The advertising salesmen of the technical journals should explain to potential advertisers the urgent need for product information to be placed in the hands of the technical people who actually make the recommendations on what to buy, and who may write single source justifications for buying unique products. There remains a need for the general advertisement and direct sales effort to appeal to management and procurement, where the final decisions are made.

E. J. Ramaley
Mfg. Research Engr.
Columbus, Ohio

Soviet Instrumentation Journals Translated

A National Science Foundation grant will enable the Instrument Society of America (ISA) to continue its program of Russian technical journal translations.

The ISA's Soviet Instrumentation and Control Translation Series incorporates the following Soviet Journals: *Zavodskaya Laboratoriya* (Industrial Laboratory); *Pribory i Tekhnika Eksperimenta* (Instruments and Experimental Techniques); *Avtomatika i Telemekhanika* (Automation and Remote Control); and *Izmeritelnaia Tekhnika* (Measurement Techniques).

Industrial Laboratory is published by the Ministry of Light Metals, USSR, and contains articles on instrumentation for analytical chemistry and physical and mechanical methods of materials research and testing. There are approximately 125 pp. per monthly issue.

Instruments and Experimental Techniques is published bi-monthly by the Academy of Sciences, USSR. The publication deals with the function, construction, application, and operation of instruments in various fields of experimentation.

Automation and Remote Control is considered to be a leading Soviet journal in the automatic control field. All phases of automatic control theories and techniques are covered in its approximately 150 pp. per issue.

Measurement Techniques is designed for those engaged in the study and application of fundamental measurement.

For subscription information, write: *Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pa.*

Second Producer Joins Magnesium Field

Calumet & Hecla, Inc., recently entered the magnesium producing business through a merger with Brooks & Perkins, one of the foremost magnesium fabricators. Alamet (Alabama Metallurgical Corp.) is the name of the venture. The question: Why Calumet & Hecla Got Into The Magnesium Business was answered by H. Y. Bassett, president of Calumet & Hecla, at the 15th Annual Convention of The Magnesium Association in New York.

Their decision to rival Dow Chemical Co. in primary magnesium manufacture came as a result of surveys indicating that an acceleration of military programs . . . increasing production of missiles . . . and a growing use in civilian applications made the magnesium field an attractive one to enter.

Figures for 1958 indicate that the three primary uses for magnesium were of a metallurgical nature. Alloying for other metals took 11,415 short tons of magnesium . . . aircraft and missiles, 9800 short tons . . .and strict metallurgical applications, 7900. The total of 29,115 represents approximately 60 pct of that used.

Meetings Listed for British Metallurgists

The 1960 Annual General Meeting of The Iron and Steel Institute will be held in London May 3-5.

A symposium on wide strip, including operational, metallurgical, and engineering aspects of wide strip and tin plate will comprise a major portion of the meeting. Concurrently, a meeting on The Determination of Gases in Metals will be staged May 3-4. The Iron and Steel Institute, The Institute of Metals, and Society for Analytical Chemistry are co-sponsoring this meeting. Two other sessions for the discussion of metallurgical papers will also be held.

Then, on May 29-June 11 The Iron and Steel Institute will hold a special meeting in Italy with the Associazione di Metallurgia. A series of plant visits is planned, with stops at Milan, Rapallo, Rome, and Naples.

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FILMS

► The Silicones div. of Union Carbide Corp. has produced a 12 min sound-color film describing the uses of its new mold wash called *Sinch*. The film shows the product in operation at Colorado Fuel and Iron Corp. and Sharon Steel Corp. facilities. Any group interested in borrowing a copy of the film should write: *Silicones Division, Union Carbide Corp., 30 East 42nd St., New York 17.*

GRANTS

► Ten engineering schools throughout the country are the benefactors of a $19.5 million total grant by the Ford Foundation. Purpose of the grants is to modernize engineering teaching through the improvement of faculties and development of new and better courses.

The Massachusetts Institute of Technology received the largest grant, $9,275,000. The California Institute of Technology, $3,200,000; Carnegie Institute of Technology, $2,250,000; University of California at Los Angeles, $1,200,000; University of Michigan, $1,175,000; Case Institute of Technology, $1,000,000; University of Illinois, $275,000; Purdue University, $275,000; Stanford University, $200,000; and the University of Wisconsin, $200,000.

In making the announcement, Ford Foundation president Henry T. Heald noted that, "In the last two decades a revolution has been underway in the practice of engineering, yet engineering education, the gateway to professional practice, has lagged behind."

More than half the grants are intended to bolster faculties with qualified engineers. Fifteen professorships, including seven at MIT, will be created. Faculty salaries will also be improved, teaching and research fellowships set up, and short-term residencies established.

BOOKS

► *Ceramics and Refractories* lists all reports of research in ceramics and refractories available from the Office of Technical Services, US Dept. of Commerce.

The 21-pp listing reports dealings with ceramic, enamel, and refractory coatings, and the high-temperature and electrical properties of ceramics. Many of the documents resulted from research by the Army, Navy, Air Force, Atomic Energy Commission, and other US Government agencies. Others are German technical papers captured during World War II. All are for sale, some in printed form, others on microfilm or photocopy.

Order CTR-373 *Ceramics and Refractories*, 1930-1959, from the Office of Technical Services, US Dept. of Commerce, Washington 25, D.C. Price of the catalog is 10¢.

List ISI Translations

Translations from French, German, and Russian are mentioned in the Iron and Steel Institute's most recent listing.

Translation #1386 is *Measuring the Wear of Blast-Furnace Linings By Means of Radio-Active Isotopes*, by A. Schepers and F. R. Light, appearing in the May, 1959, issue of *Stahl and Eisen*. *Oxygen in Blast Furnace Smelting*, #1424 by M. A. Shapovalov, first appeared in *Kislorod* in 1958. *Relations Between Brittleness at High and Low Temperature in 18-8 Type Austenitic Steels*, translation #1451 by A. Gueussier and R. Castro, made a 1958 appearance in *Revue de Metallurgie*.

For information on these and other available translations, address the *British Iron & Steel Industry Translation Service, The Iron and Steel Institute, 4 Grosvenor Gardens, London, S. W. I.*

La Revue de Metallurgie was created in 1904 by Henry Le Chatelier. In June 1959 it changed format, now appearing in two separate monthly parts.

One part, which preserves the title **Revue de Metallurgie,** is devoted particularly to applied metallurgy, especially the manufacture and working of ferrous and nonferrous metals.

It also includes economic and statistical reports, as well as news of activities of the Societe Francaise de Metallurgie and related institutions.

The second part of the magazine maintains the scientific character of the former publication and, as in the past, includes separate sections devoted to original papers and to abstracts. The title of this part is **Memoires Scientifiques de La Revue de Metallurgie.**

Subscription rates for 1960

Revue de Metallurgie	$16.50
Memoires Scientifiques de la Revue de Metallurgie	$35
Both publications jointly	$47

new books

Books that are marked (•) may be ordered through AIME. Address Irene K. Sharp, AIME Book Dept., 29 W. 39 St., New York 18, N. Y. A discount is given whenever it is possible.

The Nimonic Alloys, by W. Betteridge, *St. Martin's Press, Inc.,* New York, 332 pp., $15, 1959—The search for alloys capable of showing strength and creep-resistance under extremely severe conditions of temperature and stress led to work on the nickel-chromium system which culminated in the development of precipitation-hardenable alloys of the Nimonic series. The information deals mainly with the metallurgical characteristics of the alloys, their mechanical and physical properties, as well as methods of treatment. Manufacturing and processing techniques are discussed only briefly. •

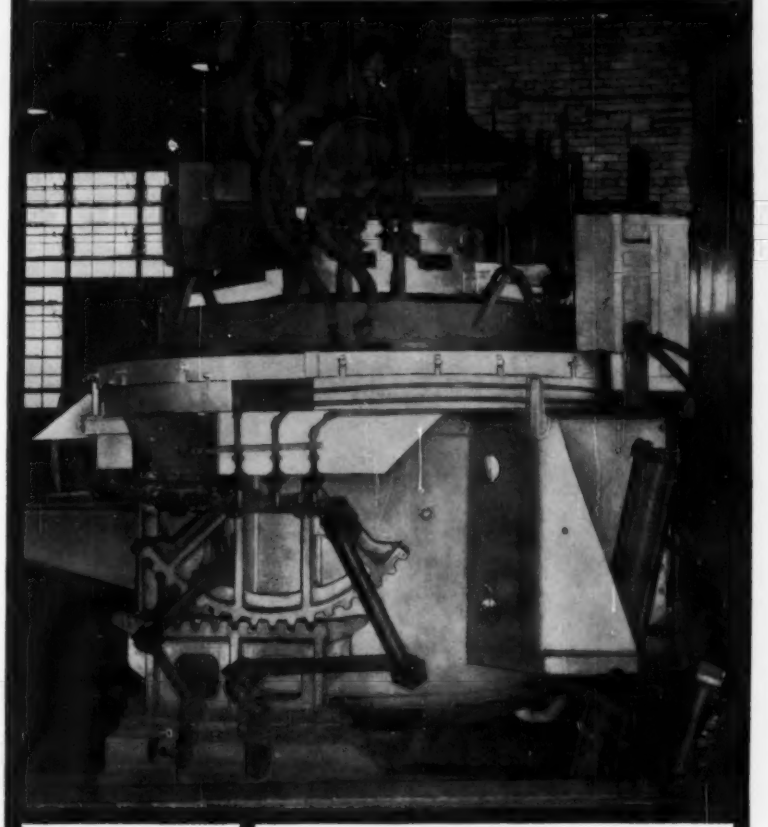
Fabrication of Molybdenum, by the *American Society for Metals,* Cleveland, 221 pp., $6.50 (paper), 1959—A common technological foundation for the fabrication of molybdenum is sought in this series of papers. Techniques used to form, weld, protect, and fabricate molybdenum as practiced by workers in the metal are illustrated. •

Symposium on Solvent Extraction in the Analysis of Metals, by the *American Society for Testing Materials,* Philadelphia, 54 pp., $2.25, 1958—This compendium of papers covers the following topics: convergence of tie lines in ternary liquid systems and its application to liquid extraction . . . metals analysis with Thenoyltrifluoracetone . . . use of tri-n-octylphosphine oxide in analytical chemistry . . . eight-hydroxyquinaldine extractions applied to the analysis of metals . . . and the use of organic solvents in flame photometry. •

Preparation of Single Crystals, by W. D. Lawson and S. Nielson, *Academic Press, Inc.,* New York, 255 pp., $8.80, 1958—Concerned with the practice of growing purer and more perfect single crystals of semi-conducting compounds, the authors begin with a discussion of techniques for growing crystals. Growth from the melt and from vapor are especially considered, with details for the construction of such apparatus given in outline. Methods for the purification of the starting material and the semi-conductors themselves is also discussed, plus the techni-

(Continued on page 796)

CONTROL ELECTRIC FURNACE FUMES



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After years of development, Pangborn now offers effective control of smoke, fumes and dust from electric melting furnaces with minimum interference to furnace operations and maintenance. The hood design is based on the fundamental dust control principle of confining and capturing fumes and dust immediately adjacent the source. Effective control is secured with substantially reduced exhaust air volumes.

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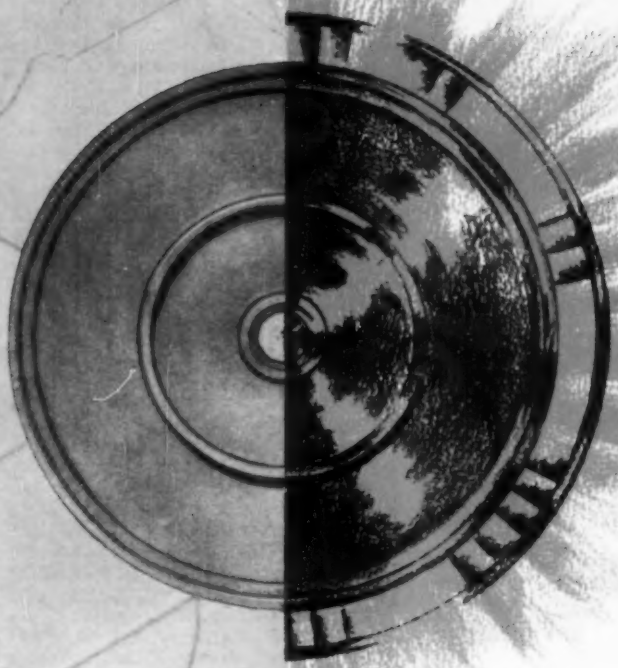

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Typical Mechanical Properties

TENSILE PROPERTIES:	Room Temp.	1400° F
Ultimate Strength, psi	200,000	145,000
.2% Yield Strength, psi	150,000	125,000
.02% Yield Strength, psi	135,000	110,000
Elongation (% in 2")	15	18
Reduction in Area, %	18	20

STRESS RUPTURE:	Combination Smooth and Notch Bar	Smooth Bar
Temperature, ° F	1350	1650
Stress, psi	85,000	25,000
Life, Hours	100	50
Elongation, %	12	12
Reduction in Area, %	14	14

Guaranteed Minimum Mechanical Properties

TENSILE PROPERTIES:	Room Temp.	1400° F
Ultimate Strength, psi	180,000	135,000
.2% Yield Strength, psi	132,000	115,000
.02% Yield Strength, psi	120,000	100,000
Elongation (% in 2")	12	13
Reduction in Area, %	14	18

STRESS RUPTURE:	Combination Smooth and Notch Bar	Smooth Bar
Temperature, ° F	1350	1650
Stress, psi	85,000	25,000
Life, Hours	40	25
Elongation, %	8	10
Reduction in Area, %	10	12

*RENÉ 41: GENERAL ELECTRIC COMPANY

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BOOKS

(Continued from page 793)

ques for handling purified materials, the preparation of semi-conducting compounds, and the detection and estimation of trace impurities. A non-mathematical approach to crystal growth and the origin of imperfections is also given. •

Advances in Inspection Techniques As Aids to Process Control in Non-Ferrous Metals Production, by *The Institute of Metals,* London, 103 pp., $4.65, 1958—This series of papers deals with the topics of automatic gage control in rolling mills . . . measurement, inspection, and automatic process control in the steel-strip finishing and tinplate industry . . . ultrasonic testing for the control of quality in the manufacture of aluminum alloys and other non-ferrous materials . . . instrumentation in ultrasonic flow detection . . . inspection of tubes for flaws and variations in thickness . . . . advances in radiographic techniques . . . and accuracy of strip-thickness measurement by beta and gamma absorption. •

Solid State Physics, vol. 8, by Frederick Seitz and David Turnbull, *Academic Press Inc.,* New York, 519 pp., $13.50, 1959—The authors, both AIME members, have brought together the most recent advances in research and application of solid state physics. This volume also marks the series' first attention to organic solids, in an article by D. S. McClure, RCA Laboratories, on organic crystals. More material of this type is planned for future editions. Contents of this 8th volume include Electronic Spectra of Molecules and Ions in Crystals . . . Photoconductivity in Germanium . . . Interaction of Thermal Neutrons with Solids . . . Electronic Processes in Zinc Oxide . . . and The Structure and Properties of Grain Boundaries. •

Elements of Materials Science, by Lawrence H. Van Vlack, *Addison-Wesley Publishing Company, Inc.,* Reading, Mass., 528 pp., $8.50, 1959—Designed to give a basic understanding of materials' structures and the conditions under which they can be used, the text is geared for all students of engineering. The author, organizer of one of the first graduate programs in the science of materials, engineering, is Prof. of Engineering Materials and Metallurgy at the University of Michigan. Introductory college mathematics is sufficient for the book's study, and since properties are related to the structure of a material, a background of introductory chemistry and physics is used to develop the structural concept. The effects of service environment upon structure and properties is also considered. •

Stress Relaxation In Structural Materials—A. M. Freudenthal, Wright Air Development Center, US Air Force, *No. PB 151516, Office of Technical Services, US Dept. of Commerce,* Washington 25, D. C., 45 pp., $1.25, 1958—Stress relaxation is discussed in relation to its physical origin, mathematical representation, experimental determination, and design significance—with particular emphasis on the interrelation between creep and relaxation in metals and polymers. Recommendations include discontinuation of uni-axial relaxation testing in favor of a method utilizing two and three-dimensional states of stress, in addition to uni-axial testing.

An Investigation of the Relationship Between Microstructure and Creep-Rupture Properties of Heat-Resistant Alloys—A. P. Coldren and J. W. Freeman, *No. PB 151421, Office of Technical Services, US Dept. of Commerce,* Washington, 25, D. C., 71 pp., $2, 1958—Progress report on influence of hot working on the properties of alloys at high temperatures. Study is being undertaken for Wright Air Development Center, US Air Force. The study's major purpose is to define the principles involved, so that they can be applied to the problem of developing optimum properties in any alloy.

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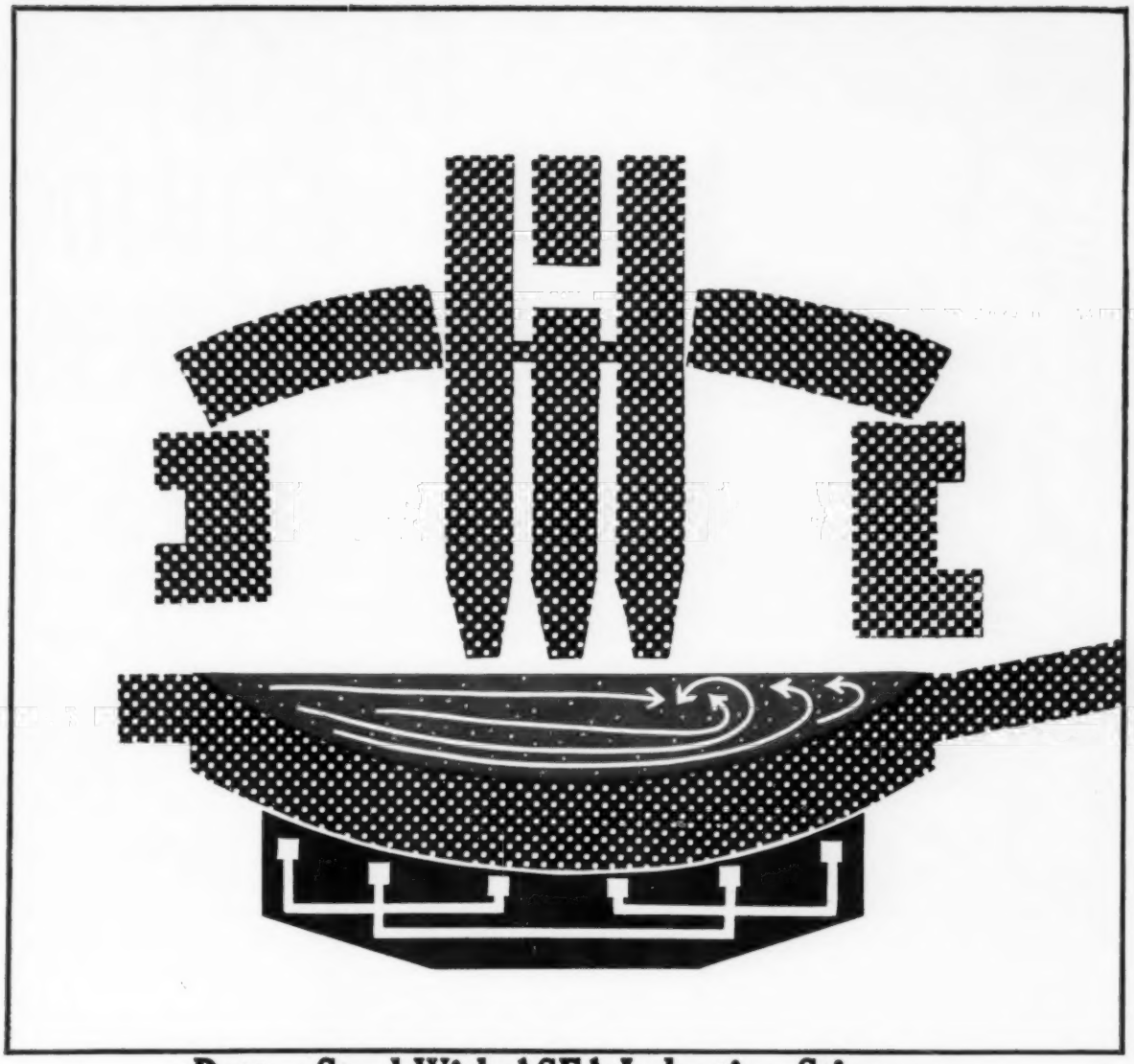

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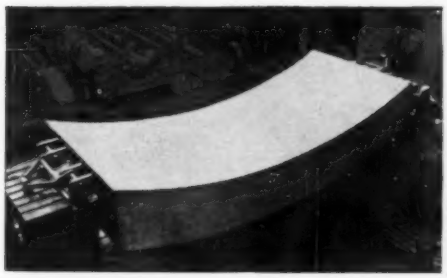

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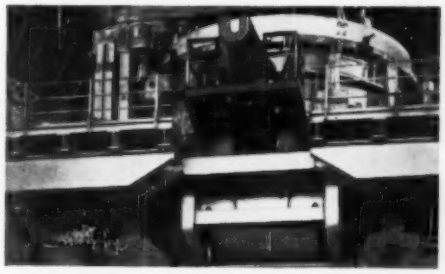

One of a series

The revealing face of an iron crystal

A single crystal is an ideal system for studying the solid state. Physicists at the General Motors Research Laboratories have turned to whisker-like growths of nearly perfect single iron crystals to investigate three intriguing phenomena: magnetic domains, dislocation defects, and—more recently—high temperature oxidation.

In this latest study, the two crystallographically different surfaces found on iron whiskers are being used to examine the anisotropy or axial-dependent nature of the oxidation process. In early stages of oxidation, the oxide patterns that form on clean surfaces have been found to be strongly dependent upon the orientation of the underlying crystal. In later stages of oxidation, tiny oxide "cilia" actually grow on the surface of the iron whisker. But these new whiskery forms of oxidation are no longer related to the crystal's surface arrangement. The next step in this program involves correlating the oxidation behavior with lattice structure defects such as vacancies and dislocations.

This type of solid state research is revealing the atomic processes underlying strength, magnetic characteristics, and corrosion resistance of metals. At GM Research, we believe the solution to practical problems is increasingly dependent on fundamental information such as this. And each solution enables us to continue to provide "More and better things for more people."

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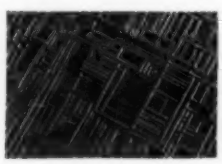

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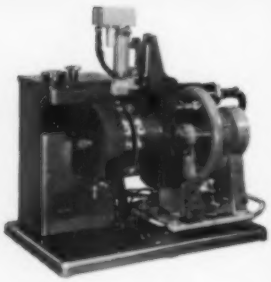
X-Ray

The use of X-ray spectrography and X-ray diffraction in industry has enjoyed tremendous expansion in the past decade, and is now universally recognized as an indispensable aid in product quality and production control. Traditionally, metallurgical applications and requirements have set the pace for the rapid development of X-ray instrumentation—and is in fact reflected in the many special instruments specifically designed to cope with metals industry problems.

This parallel progress has been of paramount and essential aid in the development of many metallurgical processes and alloys. Applications range from intimate explorations of the atomic structure of elements—on a single laboratory specimen to automatic analyses of quantities of samples—through rapid measurements of claddings or plating thickness.

One of these X-ray processes are applicable to most metallurgical analytical problems and can be engineered to specific requirements. Our Technical Department will be pleased to discuss your problem or show you how to save processing dollars, without obligation whatever.



UNIVERSAL VACUUM X-RAY SPECTROGRAPH

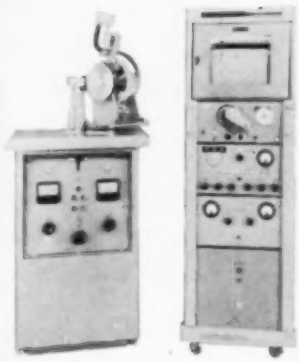
The new Norelco Universal Vacuum X-ray Spectrograph embodies maximum inherent flexibility by permitting operation with air, helium or vacuum. Evacuating the X-ray path provides higher intensities in the entire range of elements from #12 (magnesium) through #30 (zinc), and is of particular importance in the range of elements up to sulphur (#16).

New design features include:

SPECIMEN CHANGER — permits simultaneous top loading of four multi-purpose specimen holders and successive analysis of samples without breaking vacuum.

CRYSTAL CHANGER — holds two externally selectable analyzing crystals which permits an extremely broad analyzing range.

DETECTORS — Scintillation and flow-proportional detectors are both mounted on goniometer arm and are available for selective usage.



X-RAY DIFFRACTOMETER

Permits automatic recording of the diffraction spectrum by the addition of a wide range goniometer and electronic circuit panel to the basic diffraction unit. High speed detectors and electronic circuitry used in place of diffraction cameras provide rapid and more accurate determinations.

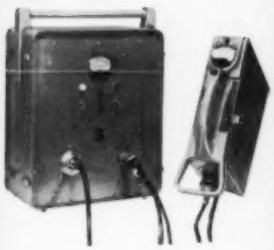
BASIC DIFFRACTION UNIT

Power source for X-ray diffraction or spectrography this fully regulated unit provides up to 50 MA and 50 KV for X-ray diffraction, diffractometric or spectrographic applications.

COMPLETE X-RAY SPECTROGRAPH

Permits rapid, accurate, non-destructive analysis of elements within a sample regardless of free or combined state. Chart position of the spectral peaks identify elements; quantity present is indicated by the height of the peak. A variety of special spectrographic attachments may be used—including the standard, universal-vacuum, and bulk. The latter is indicated with large slug specimens up to ten inches wide and two inches thick.

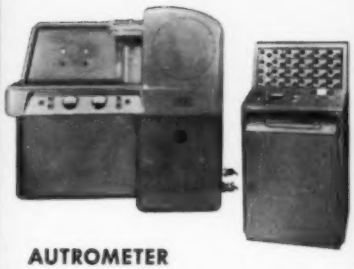
Spectrography and Diffraction



"PORTASPEC" — PORTABLE X-RAY SPECTROMETER

Lightweight and easily portable, the new "Portaspec" can be used for in-process control of metals, alloys and chemicals, for assaying, field checking of leaded fuels, identification and sorting of plate and bar stock, plating thickness gauging, film thickness measurements and other related applications.

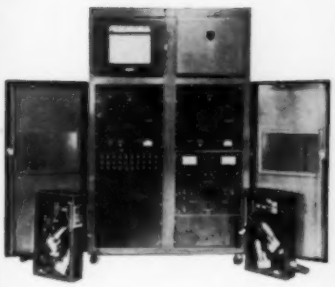
The "Portaspec" consists of two units: the first, a detector head or probe, contains a new X-ray tube, a lithium fluoride crystal, two collimators and an argon filled Geiger counter. The second unit is the power supply which provides the necessary voltage.



AUTROMETER

A completely automatic multi-indexing X-ray spectrograph designed to sequentially analyze up to twenty-four elements in a single sample. The Autrometer provides quantitative analysis within a wide range of selectable statistical precisions, using the X-ray spectrum for comparative analysis of elements ranging from #12 through all eighty-seven of the heavier elements. This is the first X-ray spectrographic instrument capable of routinely accumulating complex analytical data and presenting it in a simplified form by comparing the sample with a standard.

Metallurgical applications include its use as a quality control instrument by major producers of stainless steel and zinc to maintain critical alloying specifications.



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Single or dual head for measuring the thickness of the coatings on one or both sides of stationary or rolling base stock. This unique spectrographic procedure permits an accuracy of .01 pounds per base box, (in the case of tin), at line speeds up to 900 feet per minute. The pass band variation is plus or minus ⅛ inch. A special version of this gage permits determining the thickness of galvanized coatings.

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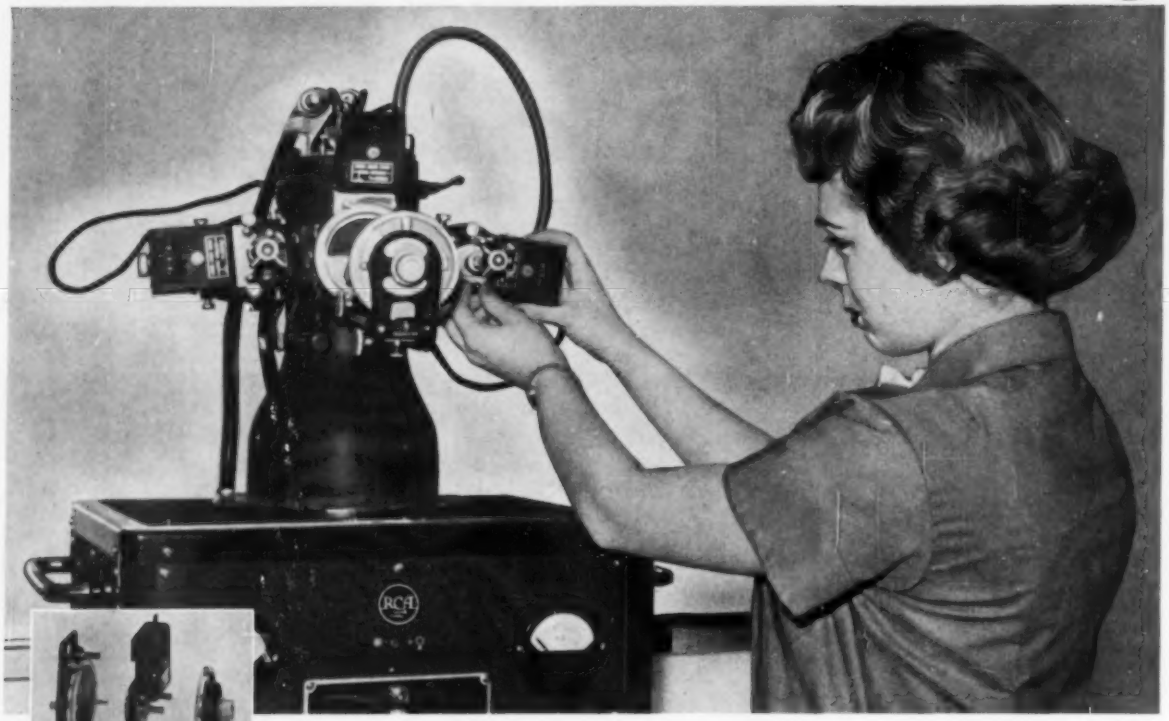
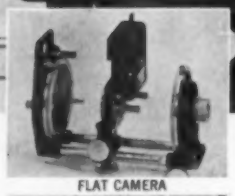
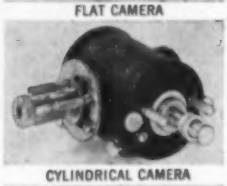



FLAT CAMERA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Complete RCA X-Ray Diffraction Equipment for all Types of Film Studies

Think of it—a complete x-ray diffraction facility for film studies can be yours now for less than $4,000.00. A typical installation could include: a Crystalloflex II X-Ray Diffraction Generator complete with two powder cameras, a flat camera, and a stereo-microcamera, a copper target x-ray tube and camera carriers. Other combinations, with prices varying according to the selection, could include both one and two radian cylindrical cameras, flat cameras and the very versatile 70mm. film with one radian cylindrical camera which can be used for powder diffraction, symmetrical back reflection work and rotating crystal layer line diagrams. A wide variety of additional cameras, x-ray tubes with other targets, and attachments for special specimen handling are also available.

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RAMTITE No. 25 is an important member of the Ramtite family of plastic refractories. There are numerous varied uses for RAMTITE No. 25. May we see if this monolithic refractory of longevity is adaptable for your particular needs? You will be under no obligation to have us investigate.

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NEW . . . instrument for controlling carbon without cooling . . . from

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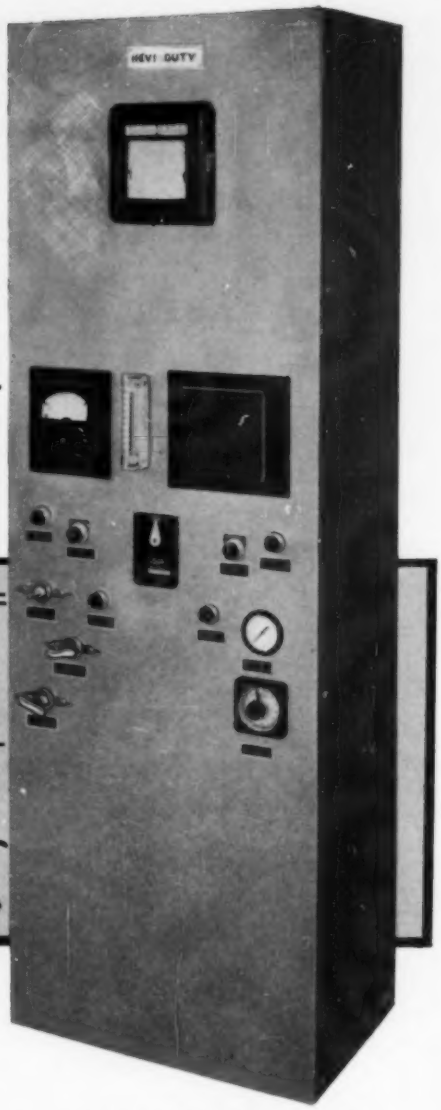
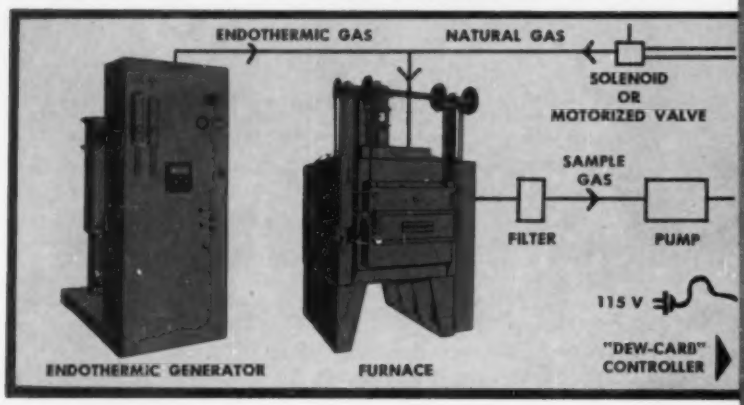


"Dew-Carb" Controller measures dew point . . . controls atmosphere carbon



Provides instantaneous response to sudden change of dew point of furnace atmosphere.

Assures precise measurement of moisture in furnace atmosphere — minus 5° to plus 60° F. dew point.

Does not require cooling of gas sample.

Hevi-Duty's new "Dew-Carb" Controller operates on a wet-dry bulb principle, measuring *precisely* the dew point in controlled atmosphere for furnace processing — bright hardening, carbon restoration, carburizing . . . controlling of surface carbon concentration and depth characteristics. No chemicals, such as lithium chloride, are required in this system.

Hevi-Duty's "Dew-Carb" Controller can be utilized in three types of furnace applications:

1. To *monitor* endothermic generator gas, or the gas within the furnace.

2. To *measure* dew point and instantaneously regulate the carbon in endothermic atmosphere. Instrument can be adapted to either generator or furnace . . . can be used with one generator supplying endothermic gas to several furnaces . . . gas for each furnace can be separately measured.

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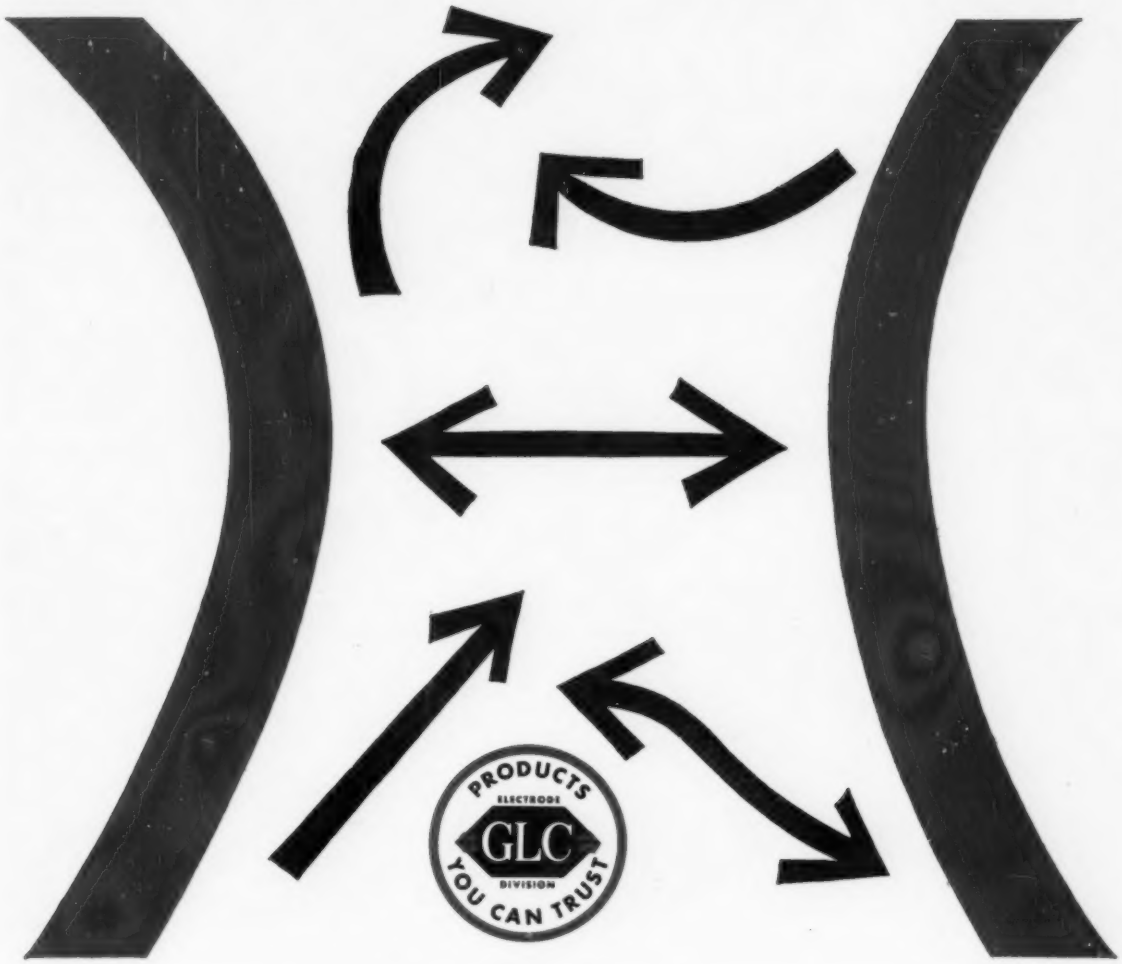

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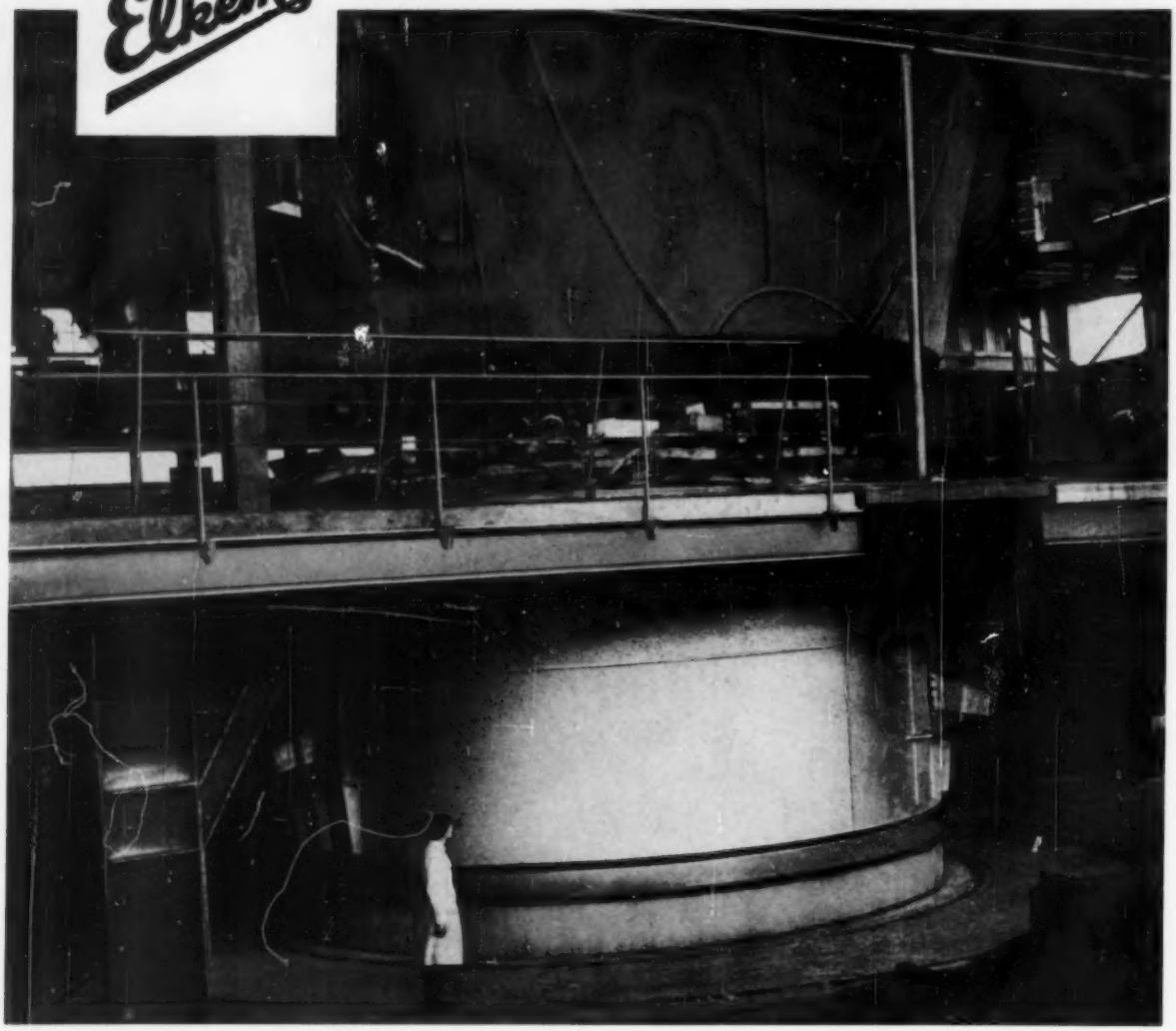

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EFC Attendance

1943	414	1949	585	1954	882
1944	569	1950	620	1955	949
1945	500	1951	752	1956	979
1946	546	1952	823	1957	1070
1947	569	1953	749	1958	950
1948	534				

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17TH ANNUAL ELECTRIC FURNACE PROGRAM

Sponsored by the Electric Furnace Committee of the Iron and Steel Division, The Metallurgical Society of The American Institute of Mining, Metallurgical, and Petroleum Engineers

Cleveland Hotel, Cleveland — December 2, 3, and 4, 1959

REGISTRATION

Wednesday, Thursday, and Friday, December 2, 3, and 4—8:30 am to 5:00 pm—Mezzanine.

TUESDAY, DECEMBER 1

6:30 pm—Rose Room

Business Meeting:
Electric Furnace Committees Annual Dinner and Business Meeting

WEDNESDAY, DECEMBER 2

Authors and Chairmen Breakfast: 8:00 am—Parlors 1-3. Authors and session chairmen will meet for breakfast followed by an opportunity to plan final details with regard to the schedule of papers for each session.

Joint Technical Session

WEDNESDAY, DECEMBER 2

9:30 to 9:45 am—Wedgwood Ballroom

General Session

Welcoming Remarks:
By P. R. Gouwens, Chairman, Committee for the Seventeenth Annual Conference.

Response:
By A. C. Ogan, Chairman, Electric Furnace Committee—Announcements and Reports.

9:45 am to 12:30 pm—Wedgwood Ballroom

Consumable Electrode Melting

(Arranged by Physical Chemistry of Steelmaking Committee)

Chairmen:
E. R. Saunders, Chairman, Product Analysis Section, Union Carbide Metals Co., Cleveland, Ohio

F. C. Langenberg, Manager of Process Research, Crucible Steel Co., Pittsburgh, Pennsylvania

1. **European Developments in Consumable Electrode Melting:**
   Paper by W. J. Childs, Professor of Metallurgy, Rensselaer Polytechnic Institute, Troy, N. Y.

2. **Electrical Behavior of Consumable Electrode AC Arcs in Variable Pressure Systems:**
   Paper by T. E. Butler, Research Assistant, and R. P. Morgan, Research Metallurgist, Union Carbide Metals Co., Niagara Falls, N. Y.
   Discussion: W. J. Childs, Professor of Metallurgy, Rensselaer Polytechnic Institute, Troy, N. Y.

3. **New Developments in the Consumable Electrode Melting of Reactive Metals:**
   Paper by S. J. Noesen, Research Metallurgist, General Electric Co., Schenectady, N. Y.
   Discussion: E. W. Johnson, Advisory Physical Chemist, Westinghouse Electric Corp., Pittsburgh, Pennsylvania.

4. **Consumable Electrode Melting of Steels and High-Temperataure Alloys:**
   Paper by R. M. Atkinson, Metallurgist, and J. Veil, Consumable Electrode Engineer, Carpenter Steel Co., Reading, Pa.
   Discussion: R. C. Buehl, Research Engineer, Crucible Steel Co. of America, Midland, Pa.

ANNUAL DINNER

Thursday, December 3

6:30 pm—Whitehall Room—Reception and Cocktail Party for dinner guests.

7:00 pm—Wedgwood Ballroom—Dinner

Toastmaster: Daniel R. Loughrey, Coordinator of Steelmaking, Jones Laughlin Steel Corp., Pittsburgh, Pa, and Chairman of National Open Hearth Steel Committee.

Speaker: William E. Umstattd, Chairman of Executive Committee, Timken Roller Bearing Co., Canton, Ohio.

Ingot Technical Session

WEDNESDAY, DECEMBER 2

2:00 to 5:00 pm Wedgwood Ballroom

Refractories

Chairmen:

H. M. Parker, Superintendent, Melting, Armco Steel Corp., Butler, Pa.
J. H. Bischoff, Assistant Superintendent, Steel Department, Bethlehem Steel Co., Bethlehem, Pa.

1. **Castable Electrode Rings:**
   Paper by H. M. Parker, Superintendent, Melting, Armco Steel Corp., Butler, Pa.
   Paper by Louis Cotton, Assistant Superintendent, Electric Furnace Department, Duquesne Works, United States Steel Corp., Duquesne, Pa.

2. **Roof Construction:**
   (a) **Evaluation of High Alumina Roofs:**
   Paper by J. M. Murphy, Ceramics Engineer, Duquesne Works, United States Steel Corp., Duquesne, Pa.
   (b) **Use of High Alumina Roofs:**
   Paper by Ralf Wood, General Foreman, Electric Furnace, Sheffield Division, Armco Steel Corp., Kansas City, Mo.
   (c) **Use of High Alumina Roofs:**
   Paper by H. M. Parker, Superintendent, Melting, Armco Steel Corp., Butler, Pa.
   (d) **New Developments in Basic Roofs for Electric Furnaces:**
   Paper by W. C. Kollman, Superintendent, Electric Furnaces, Crucible Steel Co. of America, Midland, Pa.
   Discussion: C. E. Grigsby, Service Research Consultant, General Refractories Co.
   (e) **Progress Report on Castable Refractories:**
   Paper by J. D. McCullough, Chief Engineer, Refractories Division, Babcock and Wilcox Co., New York, N. Y.

3. **Quality Control of Ladle Refractories:**
   Paper by R. E. Hauser, Research Engineer, Ceramics, Bethlehem Steel Co., Bethlehem, Pa.

4. **A Study of Hot-Topping Practices:**
   Paper by K. V. Smith, Chief Development Metallurgist, and D. V. Roloff, Ceramic Engineer, Gary Works, United States Steel Corp., Gary Ind.

Past Registrants of the

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You are entitled to purchase, at this time and at the special rate, the following available volumes of the Proceedings of the Electric Furnace Steel Conference at $7.00 per volume ($10.00 to non-registrants)

Volume 16 (1958)
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Castings Technical Session

WEDNESDAY, DECEMBER 2

2:00 to 5:00 pm—Cleveland Room

Quality Control of Electric Furnace Melting

Chairmen:

John McBroom, President, Stainless Foundry & Engineering Inc., Milwaukee, Wis.
G. J. Grott, Assistant Plant Manager, Michigan Standard Alloy Casting Co., Detroit, Mich.

1. **Effect of Various Deoxidizers on Cast Steel:**
   Preprinted paper by C. E. Sims, Consultant, Battelle Memorial Institute, Columbus, Ohio, and C. W. Briggs, Technical and Research Director, Steel Founders Society, Cleveland, Ohio.

2. **Joint Effect of Sulphur and Rare Earth Metals on the Mechanical Properties of Cast Complex Low-Alloy Electric Furnace Steel:**
   Preprinted paper by R. D. Engquist, formerly Senior Research Metallurgist, American Steel Foundries, East Chicago, Ind. (now with Hughes Research and Development, Culver City, Calif.)

3. **Melting Practice to Produce Extra Low-Sulphur Carbon Steel:**
   Paper by A. J. Kiesler, Research Associate, General Electric Co., Schenectady, N. Y.

"Special Arc" Technical Session

WEDNESDAY, DECEMBER 2

2:00 to 5:00 pm—Whitehall Room

Raw Materials and Special Alloys

Chairmen:

W. M. Kelly, Assistant Technical Director, Union Carbide Metals Co., Niagara Falls, N. Y.
Roger McClure, Works Manager, Tennessee Products and Chemical Corp., Rockwood, Tenn.

1. **Beneficiation of Low-Grade Domestic Chrome Ores:**
   Paper by L. H. Banning, Project Coordinator, Pyrometallurgical Laboratory, and W. A. Stickney, Project Coordinator, Mineral Dressing Laboratory, United States Bureau of Mines, Albany, Ore.
   Discussion: H. R. Spedden, Director of Research, Union Carbide Ore Co., Sterling Forest, N. Y. Mark Geigel, Chief Metallurgist, Chromium Mining and Smelting Co., Chicago, Ill.

2. **Raw Materials Handling in a Ferro-Alloy Plant:**
   Paper by R. A. Davidson, Chief Plant Engineer, Vanadium Corp. of America, Cambridge, Ohio.
   Discussion: H. W. Bronson, Product Manager—Manganese, Union Carbide Metals Co., Niagara Falls, N. Y.

(Continued on next page)

"Special Arc" Technical Session (Continued)

3. **Reducing Agents in the Submerged-Arc Manufacture of Ferro-Alloys:**
   Paper by H. D. Wedge, Metallurgist, and A. D. Gate, Technical Director, Beverly Plant, Interlake Iron Corp., Beverly, Ohio.
   Discussion: Murray C. Udy, Director of Research, Strategic-Udy Processes, Inc., Niagara Falls, N. Y.
4. **Electrothermic Reduction of Northwest Silicas in Submerged-Arc Furnaces Equipped with Rotary-Type Regulators:**
   Paper by W. E. Platte, Works Manager, National Metallurgical Corp., Springfield, Ore.
   Discussion: L. E. Othmer, Keokuk Electro-Metals Co., Div. of Vanadium Corp. of America, Keokuk, Iowa.

Castings Technical Session

THURSDAY, DECEMBER 3

9:30 am to 12:30 pm—Cleveland Room

Degassing of Steels for Foundry Melting Practice

Chairmen:
A. F. Gross, Chief Metallurgist, The Ohio Steel Foundry Co., Springfield, Ohio.
C. B. Williams, Works Manager, Massillon Steel Casting Co., Massillon, Ohio.

1. **Gas Solubility of Iron and Nickel-Base Alloys:**
   Paper by F. W. Boulger, Chief, Division of Ferrous Metallurgy, Battelle Memorial Institute, Columbus, Ohio.
2. **Ladle and Furnace Degassing of Alloy and Carbon Steels:**
   (a) **Experiences With Ladle to Ladle Stream Degassing for Steel Castings:**
   Preprinted by Edward Dyble, Plant Metallurgist, and G. E. Danner, Director of Research and Metallurgy, Erie Forge Manufacturing Co., Erie, Pa.
   Discussion: N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.
   (b) **Vacuum Degassing of Steels for Aircraft Uses:**
   Paper by J. K. Dietz, Design Engineer, Denver Div., Martin Co., Denver, Colo.
   Discussion: Jack Keverian, Manager of Applied Research, Foundry Department, General Electric Co., Schenectady, N. Y.
   E. M. Anger, Chief Metallurgist, The Duraloy Co., Scottdale, Pa.
3. **Equipment Used in Vacuum Degassing in the Foundry:**
   Paper by W. F. Hipple, Assistant Sales Manager, Ajax Electrothermic Div., Ajax Magnethermic Corp., Trenton, N. J.

Electric Furnace Steel Suppliers who have parlors for entertaining have been requested and are anxious to cooperate in closing their rooms during technical sessions and the dinner on Thursday. Please help them cooperate by voluntarily leaving or avoiding their rooms at these times.

"Special Arc" Technical Session

THURSDAY, DECEMBER 3

9:30 am to 11:00 am Whitehall Room

Manufacture of Calcium Carbide and Refractories

Chairmen:
W. J. Fulton, Vice President and General Manager, Midwest Carbide Corp., Keokuk, Iowa.
A. C. Haskell, Jr., Chief, Process Metallurgy, Research Dept., Titanium Alloy Manufacturing Division, National Lead Company, Niagara Falls, N. Y.

1. **Use of Vertical Kilns for Production of Lime for Manufacture of Calcium Carbide:**
   Paper by D. E. Stingel, Production Manager, Union Carbide Olefins Co., New York, N. Y.
   Discussion: S. R. Hathaway, Superintendent of Processing, Mississippi Lime Co., Ste. Genevieve, Mo.
2. **Effect of Some Calcium Carbide Process Variables on Acetylene Generator Operation:**
   Paper by R. L. Perks, Assistant Superintendent, Carbide Division, Shawinigan Chemicals Ltd., Shawinigan, Que.
   Discussion Heywood Alford, Engineer, National Carbide Co., Calvert City, Ky.
3. **Electric-Arc Fusion-Cast High-Alumina Refractories:**
   Preprinted paper by W. A. Miller, Supervising Engineer, and K. H. Sandmeyer, Manager, Production Engineering Dept., Refractories Div., Carborundum Co., Falconer, N. Y.
   Discussion: G. J. Easter, Director of Research, Electro Refractories and Abrasives Corp., Buffalo, N. Y.

(Recess at 11:00 am to attend paper on Iron Ore Reduction in Wedgwood Ballroom.)

Ingot Technical Session

THURSDAY, DECEMBER 3

9:30 to 10:30 am—Wedgwood Ballroom

Construction and Tool Steels

Chairmen:
W. C. Kollman, Superintendent, Electric Furnace, Crucible Steel Co., of America, Midland, Pa.
F. I. Marshall, Melting Superintendent, Babcock and Wilcox Co., Beaver Falls, Pa.

(Continued on next page)

Ingot Technical Session (Continued)

1. **Temperature Controls and Measurements:**
   Paper by N. L. Samways, Senior Research Engineer, T. E. Dancy, Senior Research Supervisor, K. Li, Research Associate, and J. Halapatz, Research Associate, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

2. **Correlation Between Tap Temperature, Ladle Temperature, and Pouring Stream Temperatures:**
   Paper by W. H. Burr, Chief Development Metallurgist, Duquesne Works, United States Steel Corp., Duquesne, Pa.

10:30-12:30 pm—Wedgwood Ballroom

Construction Steels

Chairmen:
W. C. Kollman, Superintendent, Electric Furnace, Crucible Steel Co. of America, Midland, Pa.
F. I Marshall, Melting Superintendent, Babcock and Wilcox Co., Beaver Falls, Pa.

1. **Oxygen-Fuel Gas Burners for Scrap Meltdown in Electric Furnaces:**
   Paper by G. W. Hinds, Project Engineer, and A. L. Hodge, Associate Manager, Gas Process Development, Linde Company, Newark, N. J.

2. **Recent Developments in the Strategic-Udy Process for the Direct Reduction of Iron Ore:**
   Paper by Murray C. Udy, Director of Research, Strategic-Udy Processes, Inc., Niagara Falls, N. Y.

3. **Iron Ore Reduction by Electric Power:**
   Paper by N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.

Ingot Technical Session

THURSDAY, DECEMBER 3

10:30 to 12:30 pm—Parlors 34-36

Tool Steels

Chairmen:
B. H. Brown, Melting Superintendent, Jessop Steel Co., Washington, Pa.,
H. O. Beaver, Jr., Production Metallurgist, The Carpenter Steel Co., Reading, Pa.

1. **Effect of Melt Shop Practice on Cleanliness for High-Speed Steel:**
   Preprinted paper by W. L. Havekotte, Supervisor, Process Research, Firth-Sterling, Inc., McKeesport, Pa.

Discussers:
R. A. Frost, Product Metallurgical Engineer, Vanadium Corp. of America, Cambridge, Ohio.
B. M. Hamilton, Quality Control, Atlas Steels Ltd., Welland, Ont.
Charles Sawyer, Works Manager, and F. F. Steele, Melting Superintendent Vanadium-Alloys Steel Co., Latrobe, Pa.
H. M. Evers, Superintendent of Melting, Universal-Cyclops Steel Corp., Bridgeville, Pa.
H. O. Beaver, Jr., Production Metallurgist, The Carpenter Steel Company, Reading, Pa.
W. E. Hartman, Melting Superintendent, Latrobe Steel Co., Latrobe, Pa.
Willis Heck, Melting Superintendent, Braeburn Alloy Steel Co., Braeburn, Pa.

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Volume 5 (1947)

THURSDAY, DECEMBER 3

2:00 to 5:00 pm—Wedgwood Ballroom

Stainless Steel Session

Chairmen:
J. C. Brown, Superintendent, Electric Furnaces, Jones & Laughlin Steel Corp., Detroit, Mich.
T. J. Wayne, Superintendent, Electric Furnaces, South Works, United States Steel Corp., Chicago, Ill.

1. **Jet Tapping for Electric Furnaces:**
   Preprinted paper by Herbert Schaaf, Jr., Technical Service Representative, E. I. du Pont de Nemours & Co., Pittsburgh, Pa.

2. **The Use of Special Additives in Stainless and Alloy Steels:**
   Paper by A. J. Nimeth, Assistant Superintendent, Electric Furnace, Jones & Laughlin Steel Corp., Detriot, Mich.
   Paper by S. J. Myford, Melting Superintendent, Copperweld Steel Co., Warren Ohio.

3. **Practical Economics in Stainless Steel Melting:**
   Preprinted paper by R. B. Shaw, General Superintendent, Melting Operations, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

4. **Exothermic Hot Topping of Stainless Steel:**
   Paper by Leon Nelson, Staff Metallurgical, Crucible Steel Co. of America, Midland, Pa.

5. **Advanced Application of Exothermic Hot-Topping:**
   Paper by T. C. McConnon, Manager, Steel Division, Pittsburgh Metals Purifying Co., Inc., Mars, Pa.

6. **Discussion of Fume Control:**
   Moderator: W. M. Patterson, Electric Melting Consultant, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

   (a) Paper by J. L. Venturini, Fuel Engineer, Bethlehem Pacific Coast Steel Corp., Los Angeles, Calif.

   (b) Paper by P. E. Lindberg, General Superintendent, Hot Metal Div., McLouth Steel Corp., Trenton, Mich.

(Continued on page page)

Ingot Technical Session (Continued)

(c) Paper by John Glasgow, Superintendent, Open Hearth Department, Jones & Laughlin Steel Corp., Cleveland, Ohio.

Panelists: J. T. Evans, Jr., Superintendent of Melting, The National Supply Co., Torrence, Calif.

C. N. Finkl, Vice President, Engineering, A. Finkl and Sons, Chicago, Ill.

P. E. Lindberg, General Superintendent, Hot Metal Division, McLouth Steel Corp., Trenton, N. J.

John Glasgow, Superintendent, Open Hearth Department, Jones & Laughlin Steel Corp., Cleveland, Ohio.

Castings Technical Session

THURSDAY, DECEMBER 3

2:00 to 5:00 pm—Cleveland Room

Pouring, Refractories, Gadgets, and Tricks

Chairmen:

A. J. Kiesler, Metallurgical Engineer, General Electric Co., Schenectady, N. Y.

C. G. Mickelson, Assistant Manager Research, American Steel Foundry, East Chicago, Ind.

1. **Phosphate-Bonded Refractories for Pouring Ladle Spouts:**
   Paper by G. J. Grott, Assistant Plant Manager, Michigan Standard Alloy Casting Co., Detroit, Mich.

2. **High-Alumina Castable Refractories for Ladles:**
   Preprinted paper by S. O. Smith, Chief Metallurgist, Texas Foundries Inc., Lufkin, Texas.

3. **Gadgets and Tricks for Foundry Melting:**
   Moderators: V. E. Zang, Vice President, Research and Development, Unitcast Corp., Toledo, Ohio.
   S. O. Smith, Chief Metallurgist, Texas Foundries Inc., Lufkin, Texas.

"Special Arc" Technical Session

THURSDAY, DECEMBER 3

2:00 to 4:00 pm—Whitehall Room

Model Characteristics and Electrode Penetration—Submerged Arc Furnaces

Chairmen:

Frank St. Vincent, General Superintendent, Interlake Iron Corp., Beverly, Ohio.

E. T. Johnson, Production Manager, Pittsburgh Metallurgical Co., Inc., Niagara Falls, N. Y.

1. **Model Characteristics of Three-Phase Submerged Arc Furnaces:**

   Paper by J. A. Persson, Research Engineer, Technology Dept., Union Carbide Metals Co., Niagara Falls, N. Y.

   Discussion: J. R. Lee, Design Engineer, Vanadium Corp. of America, Cambridge, Ohio.

   F. V. Andreae, Chief Engineer, Tennessee Products and Chemical Corp., Chattanooga, Tenn.

2. **Round-Table Discussion on Electrode Penetration: Determination of Electrode Position and Its Significance:**

   Lead-off discussions by ferro-alloy and carbide manufacturers.

(Recess at 4:00 pm to attend Panel Discussion on Fume Control in Wedgwood Ballroom)

Plant Trip

FRIDAY, DECEMBER 4

9:30 am to 4:30 pm

Plant Trip

Chartered Buses will leave from the Cleveland Hotel in the morning at 9:00 am, and return by 4:30 pm.

There is a choice of visiting either the Republic Steel Corporation, Canton, Ohio, or Babcock and Wilcox Company, Barberton, Ohio.

At Republic Steel Corporation, Canton, the plant trip will include an inspection of the No. 3 Electric Furnace shop where an induction stirrer is in operation. A visit will also be made to one of the bar shops.

At Babcock and Wilcox Company, Barberton, the plant trip will cover the following facilities: Pierce and Bar Shop, Alloy and Iron Foundry, Machine Shop and Tool Room, and Sheet and Structural Shop. Other facilities, including their Quality Control Laboratory, will be open to viewing and questions at the request of the individual touring groups.

Foreign visitors must be cleared at least one week ahead of time for both plant trips.

Cost of tickets is $3.00, including lunch.

New Book on Flat Rolled Products

"Flat Rolled Products: Rolling and Treatment," a Proceedings of the First AIME Mechanical Working Conference has been published by Interscience Publishers, Inc., 250 Fifth Avenue, New York 1, N. Y. Order your copy through them. 148 pages, $3.75.

Members of AIME may order their copy at a special price of $3.00 through The Metallurgical Society of AIME, 29 West 39th Street, New York 18, N. Y.

IMPORTANT McGRAW-HILL BOOKS

METAL FATIGUE

By George Sines, University of California, Los Angeles; and J. L. Waisman, Douglas Aircraft Company. *McGraw-Hill UCLA Engineering Extension Series.* 415 pages, $12.50.

The most rational exposition of fatigue of metals to be found in one book. The editors have sought the leading authority for each subject and put the key information into print. Critically selected bibliographies are provided, and the introduction includes a guide to fatigue literature, for those not thoroughly familiar with the field. The book presents a coordinated advanced treatment, by men who are experts, writing on their own specialties. Much of the subject matter is new.

ENGINEERING MANUFACTURING METHODS, Second Edition

By Gilbert S. Schaller, University of Washington. 682 pages, $9.50.

A straightforward revision of a book that has been very successfully used in Manufacturing Processes courses. Expanded and with new illustrations, the book presents a survey of the entire field of manufacturing in engineering and the manufacture of engineering products. To attain this goal, *every phase* of engineering manufacture is covered. In addition, the introductory chapter deals with the broader phases of management administration as applied to manufacturing.

CONSTITUTION OF BINARY ALLOYS

By Max Hansen, Metallgesellschaft A. G., Frankfurt-Main, Germany; in cooperation with Kurt Anderko, Metallgesellschaft A. G., Frankfurt-Main, Germany. *McGraw-Hill Metallurgy and Metallurgical Engineering Series.* Second Edition. 1305 pages, $35.00.

This revision and translation of the German work provides a source of reliable data concerning the constitution of binary alloy systems (phase diagrams) and the crystal structure of metallic phases. Widely scattered information in the world's metallurgical literature is analyzed and critically evaluated.

PHYSICAL METALLURGY

By C. Ernest Birchenall, Princeton University. 323 pages, $8.50.

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A PRIMER ON DEOXIDATION

What is it? Why do you do it? How do you do it? These questions and many more are here answered, in language any steelmaker can understand, by the author of "The Nonmetallic Constituents of Steel," this year's Howe Memorial Lecture.

by Clarence E. Sims and Charles W. Briggs

DEOXIDATION of cast steels can best be discussed by going back to basic principles and definitions in order to start with a common understanding. All too often, these principles are unknown, poorly understood, or simply ignored by producers of steel castings. Too many castings are being made today containing Type II inclusions which, in turn, are a result of improper deoxidation practice.

The primary purpose of deoxidation is to obtain castings free of porosity; any other effect is secondary. The ideal casting is completely sound and without porosity—one may tolerate a little porosity at times, but it is never desired.

Deoxidation may be defined as an operation or a reaction in which the oxygen concentration is lowered in liquid steel. Oxygen content is partially but never entirely eliminated, and the activity of the remaining oxygen is usually decreased to make it less effective. This latter effect is sometimes an important aspect of deoxidation.

It follows naturally that a deoxidizer is an element that has the power to decrease the oxygen content of liquid steel when added to the steel. This is accomplished by combination with the oxygen to form an insoluble compound which precipitates and floats out of the steel bath. To be able to do this, it must have a combining power for oxygen that is greater than that of any other element in the steel. In other words, it must form a very stable oxide. One way to measure the stability of an oxide is in the free energy of formation of the oxide. The free energy, ΔF, is the driving force of a reaction and is here distinguished from ΔH, the total heat of reaction, because the latter includes heat absorbed or given up as specific heat of the substances.

Table I lists the free energies of formation of some of the common oxides of concern in steelmaking reactions. They are for reactions at 1600° and 1500° C, and all are for one gram-atom of oxygen, for ready comparison. These values give at least an approximate comparison of the stability of these oxides at this temperature. It will be noted that the free energy of formation of any of the other oxides is sufficient to decompose FeO and have some left over. For example, in the reaction

$$\underset{-68,860}{2\,FeO} + Si \rightarrow 2\,Fe + \underset{-126,300}{SiO_2}\ \Delta F = -57,440\ cal$$

the difference between the heat absorbed and the heat generated is $+68,860 - 126,300 = -57,440$ cal, which is the ΔF or free energy of the reaction. These oxides, therefore, can form at the expense of FeO. Silica forms in preference to MnO and aluminum has the power to decompose silica. At 1600°C, CO is slightly more stable than SiO_2 which prompts the question of how silicon can stop the carbon boil or prevent the $\underline{C} + \underline{O}$ reaction during freezing. Fortunately, at the liquidus temperature of a medium carbon steel (1500°C), the free energies are reversed as shown in Table I. This makes SiO_2 more stable but the difference is not great. This subject will be discussed more later on.

These free-energy relationships do not tell the whole story. They are the driving force of the reaction and indicate whether the reaction is likely to occur, but they do not tell whether it will actually take place, how fast it will go, nor how far it will go. Also, the free energies of elemental substances are substantially higher than when these materials are dissolved in liquid iron. As an example, in the reaction between dissolved carbon and dissolved oxygen

$$\underline{C} + \underline{O} \rightarrow CO\ (g)\ \Delta F_{1600^\circ C} = -22,000\ cal,$$

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the free energy of the reaction is thus only 1/3 as great as that given in Table I.

The strength or potency of a deoxidizer is measured, not by how much oxygen it removes from a liquid steel, but rather by how much it leaves in the steel. The deoxidation reaction, like all chemical reactions, does not go to completion or to exhaustion of the reacting substances. As the reacting substances decrease, the concentration of the products of the reaction increase. Eventually, the free energy of these products create a driving force in the opposite direction equal to the driving force of the reaction, which results in a stalemate called equilibrium. The relation is expressed as an equilibrium constant, which for the silicon-oxygen reaction is

$$[\%\ \mathrm{Si}]\ [\%\ \mathrm{O}]^2 = \mathrm{K}.$$

K is the equilibrium constant.

It means, of course, that there is a very definite and reproducible relationship between the silicon content and the oxygen content when silicon is the principal deoxidizer. This is equally true for any other deoxidizer. As the silicon content goes up, the oxygen content must go down to keep the product constant. Such emphasis on a simple fact seems warranted because of certain statements, possibly prompted by wishful thinking, that, somehow deoxidized steels with high-oxygen content can be produced and that such steels should have superior properties. A deoxidized steel is a low-oxygen steel and the greater the degree of deoxidation the lower the oxygen content. The relation of various deoxidizers to oxygen content is shown in Fig. 1.

Both carbon and hydrogen play an important part among the deoxidizers for cast steel. Carbon, of course, is the principal strengthening constituent in steel and is used primarily for that purpose. Hydrogen, on the other hand, is an insistent interloper, never wanted, and efforts are usually made to keep its content as low as possible. Both carbon and hydrogen are unique among deoxidizers in that the products of deoxidation are gases:

$$\underline{\mathrm{C}} + \underline{\mathrm{O}} \rightarrow \mathrm{CO}\ (g)$$

$$2\underline{\mathrm{H}} + \underline{\mathrm{O}} \rightarrow \mathrm{H_2O}\ (g).$$

The prime purpose of deoxidation, as practiced, is to prevent these elements from functioning as deoxidizers during freezing of a cast steel, and thus avoid porosity.

Carbon-oxygen reaction

Silicon is the great, common deoxidizer for cast steel and is almost universally used even when other materials are also used. In Fig. 2, two lines are shown for silicon, one to represent the silicon-oxygen equilibrium at an operating temperature of 1650°C and the other at 1500°C, which is about the liquidus temperature for a medium carbon steel. It is readily apparent that silicon becomes a better deoxidizer as the temperature drops and is far more efficient at the freezing temperature of steel than at the operating temperature, when it is added.

Two lines also are drawn for the carbon-oxygen equilibrium at the same two temperatures and show that this equilibrium is affected only slightly by temperature changes. For equilibrium at 1650°C, it will be noted that, for equivalent concentrations, carbon is a better deoxidizer than silicon at any content over about 0.025 pct. How then, can silicon kill the boil; i.e., stop the carbon-oxygen reaction?

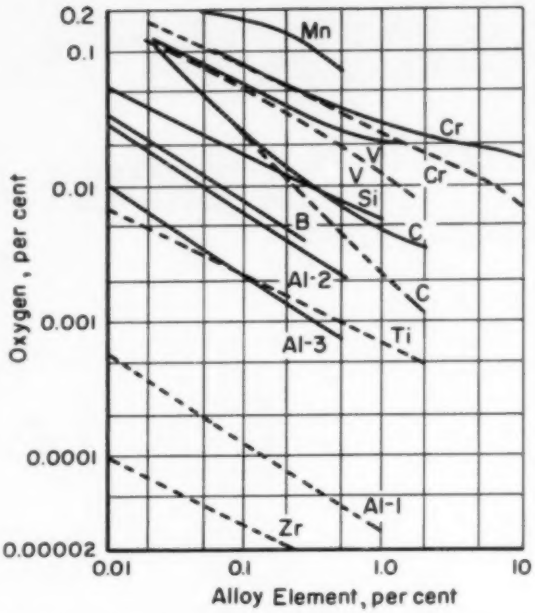

Fig. 1—Oxidation effect of various elements: solid lines, observed oxygen concentration; broken lines, oxygen activity. Note discrepancy in case of aluminum: Al-1, calculated; Al-2, Hilty and Crafts[5]; Al-3, Wentrup and Heiber[6] (from Basic Open Hearth Steelmaking, 1951, p. 671).

As has been pointed out, carbon differs from silicon in having a gaseous reaction product, CO. The standard equilibrium for the carbon-oxygen reaction is at one atmosphere pressure of CO. During the oxidizing period of a heat, this equilibrium is never reached. The dashed line of Fig. 2 (carbon observed) gives the mean values of a large number of samples taken from an open-hearth bath near the finishing period of the heat and shows the actual relation between carbon and oxygen. This is the so-called *steady state* and can be considered a pseudo-equilibrium, or better, equilibrium at higher pressures of CO. Thus, even at 1650°C, silicon can completely stop the carbon boil in a steel bath.

At the solid-liquid interface of a freezing steel, the conditions for bubble formation are much more favorable and apparently gas pressures closer to one atmosphere are effective. Under these conditions, much lower oxygen contents are necessary to prevent evolution of CO, but an examination of the equilibrium curves for silicon and carbon for 1500°C will show that silicon is adequate for the task.

Table I. Free Energies of Formation of Some Common Oxides when the Reaction Takes Place at 1600° and at 1500°C*

Reaction	ΔF Per Gram Atom O at 1600°C	ΔF Per Gram Atom O at 1500°C
Fe (l) + 1/2 O_2 → FeO (l)	−34,430	−35,630
Mn (l) + 1/2 O_2 → MnO (s)	−57,000	−59,000
C (s) + 1/2 O_2 → CO (g)	−65,900	−64,100
1/2 Si (l) + 1/2 O_2 → 1/2 SiO_2 (s)	−63,150	−65,400
2/3 Al (l) + 1/2 O_2 → 1/3 Al_2O_3 (s)	−85,500	−88,000
1/2 Ti (s) + 1/2 O_2 → 1/2 TiO_2 (s)	−68,550	−70,650
1/2 Zr (s) + 1/2 O_2 → 1/2 ZrO_2 (s)	−86,750	−89,000

* Values calculated from table of free energies in Chapter 14 of *Basic Open Hearth Steelmaking*, 1951.

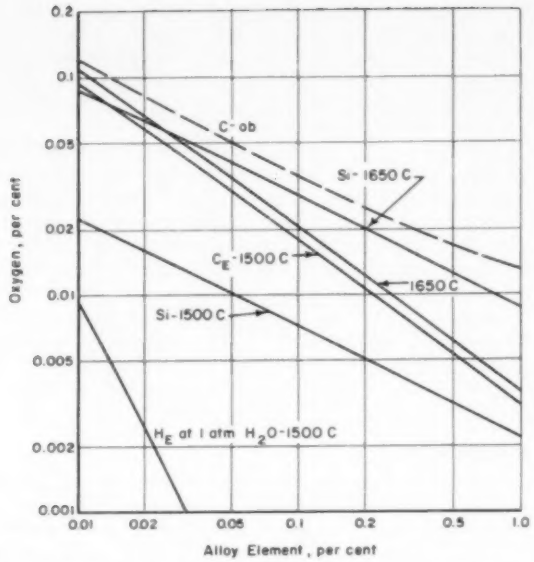

Fig. 2—Equilibrium relations of carbon, silicon, and hydrogen with oxygen in liquid steel. C-ob, average of carbon and oxygen contents of open hearth steel; C_E, C-O equilibrium with 1 atm CO; H_E, H-O equilibrium with mixture of H_2 and H_2O, partial pressure of H_2O 1 atm.

Hydrogen-oxygen

Fig. 2 contains a curve showing the equilibrium relations of hydrogen to oxygen in liquid steel which is also in equilibrium with a mixture of H_2 and water vapor in which the partial pressure of the water vapor is one atmosphere. On this basis, for equal weight percentages, hydrogen is a better deoxidizer than silicon at 1500°C. For example, both 0.2 pct Si and 0.015 pct H are in equilibrium with 0.005 pct O. This is hardly a fair comparison, however, because hydrogen is such a light element, and 0.4 at. pct Si is equivalent to 0.83 at. pct H. Thus, atom for atom, silicon is twice as strong a deoxidizer as hydrogen. It is obvious, however, that 0.015 pct H or 150 ppm is a vastly higher concentration than is ever expected in liquid steel, and it should be clear why it is not possible to have a hydrogen boil analogous to the carbon boil.

The equilibrium content of oxygen is about 0.003 pct in a medium-carbon steel containing 0.5 pct Si at the liquidus temperature. Hydrogen would have to be present in a concentration of 0.018 pct or 180 ppm to generate an escaping pressure of one atmosphere of H_2O. Numerous analyses have shown the usual hydrogen content in cast steel, at the time of pouring, to be in the range of 5 to 15 ppm. At first thought, 180 ppm seems like an impossibly high concentration. However, consideration must be given to the high initial rate of freezing of a light section casting, the sharp drop in hydrogen solubility during freezing, and the rapid diffusion rate of hydrogen at high temperatures. These factors make it logical to expect an appreciable dendritic segregation of hydrogen at the solid-liquid interface of the freezing skin. If the steel was to be poured with a hydrogen content of 9 ppm, a concentration of 20 to 1 would bring it to 180 ppm.

The hydrogen itself would exert an escaping pressure of 53 atm at a concentration of 180 ppm. The pertinent question is: With such a pressure, why cannot the hydrogen initiate bubble formation without the aid of oxygen? No good answer can be given to this question, yet evidence indicates that silicon-killed steel poured into a green sand mold may develop porosity. If a small addition of aluminum is made to the same steel, often as little as 0.01 to 0.02 pct, which is then poured into an identical green sand mold, the casting will be free of porosity. The essential difference is the active oxygen content of the liquid steel. Although hydrogen appears unable to initiate bubble formation, its high pressure will insure rapid growth when once started.

Side effects of deoxidizers

Thus, deoxidizers are used to control porosity in castings, but the law of compensation applies here as in most other things, and deoxidation is not an unmixed blessing. In other words, you have to pay for what you get. In view of this, it is advisable to select the deoxidizer which gives the best bargain.

The foregoing concludes that an element is a deoxidizer because it is chemically active and forms a stable oxide. Such an element, however, is very likely to form other stable compounds like nitrides, sulfides, and carbides. This introduces side effects which may be good, bad, or indifferent, but which must be considered when evaluating a deoxidizer.

Type II sulfides: There is one very important side effect that is common to all strong deoxidizers, so common in fact that it must be regarded as a function of deoxidation itself. It is the conversion of the large globular Type I sulfides to the eutectic Type II sulfides with resultant detriment to ductility (Fig. 3). Type II sulfides may be produced by appropriate additions of aluminum, zirconium, titanium, misch metal, or magnesium[8] in medium carbon steels, and by silicon in steels containing over 1 pct C as reported by Christopher.[8] Furthermore, it has been shown that, when oxygen has been lowered by vacuum treatment alone, Type II sulfides are formed.[25] When deoxidation is uniform or when the deoxidizer is uniformly dispersed in the steel, the transition from Type I to Type II is abrupt and complete and occurs at a definite level of deoxidation. Thus, the appearance of Type II sulfides can be used as a qualitative measure of deoxidation and the ability of an addition to produce Type II sulfides as a measure of its deoxidizing potency.

The characteristics of the various types of sulfides and the probable mechanism of their formation has been described elsewhere[4] and need not be detailed here. Suffice it to say that deoxidation largely controls the characteristics of the inclusions, and that inclusion type and quantity are the most important factors governing the mechanical property variations in steel. For a given type of inclusion, ductility will vary inversely with the total quantity. The importance of type is shown by figures obtained in a study of 150 low alloy cast steels. The proportion of steels with room-temperature V-notch Charpy values over 40 ft-lb were related to inclusion type as follows: steels with Type I sulfides, 94 pct; steels with Type III sulfides, 80 pct; and steels with Type II sulfides, 5 pct. Reductions of area that were greater than 40 per cent, were: steels with Type I sulfides, 99 pct; steels with Type III sulfides, 89 pct;

and steels with Type II sulfides, 40 pct. While it is obvious that the Type I is best and the Type II worst, there is not a simple correlation of inclusion type with ductility, because of the influence of other factors such as soundness, composition, and strength level. Also, a low-sulfur steel with Type II sulfides can have better ductility than a high-sulfur steel with Type I sulfides.

Sulfide formation: One of the important side reactions is the combination of deoxidizers with the sulfur content of the steel and the effect of the sulfides so formed on the properties of the casting. Table II illustrates the free energies of formation of some metal sulfides at 1500°C which give some indication of the likelihood of their formation in steel at that temperature. For example, MnS has twice the free energy of FeS and would definitely take precedence over the latter. The very high free energy of CaS indicates the potentiality of calcium as a desulfurizer. On the other hand, SiS_2 will not form in the presence of iron at freezing temperatures, while Al_2S_3 is not likely to form, although it has been tentatively identified in experimental steels containing abnormally high contents of both sulfur and aluminum.[5] The calculated figure for the free energy of formation for TiS appears to be reasonably reliable. Titanium reacts violently with sulfur and forms a highly stable compound. It appears to be readily capable of displacing manganese from MnS. Cerium sulfide is more stable than calcium sulfide while lanthanum sulfide is only slightly less stable. Both CeS and La_2S_3* are considerably less soluble in liquid steel than FeS and MnS.

* Recent information, not well authenticated, indicates that there is also a Ce_2S_3 under some conditions and also an LaS which is even more stable than CeS.

Nitride formation: Most strong deoxidizers also avidly combine with nitrogen, and in Table III are shown the free energies of formation of some nitrides at 1500°C. Iron nitride, which is not shown, is not stable at this temperature, but aluminum, titanium, zirconium, cerium, and lanthanum form very stable nitrides. Boron nitride is somewhat less stable. Because of the instability of iron and manganese nitrides at the freezing temperature of steel, nitrogen, when present, contributes importantly to the porosity of steel by precipitating into any bubbles formed. The high stability of deoxidizer nitrides is therefore important, and deoxidation is also denitridation, although the nitrogen content of the steel is not usually lowered.

Characteristics of deoxidizers

The method of evaluating a potential deoxidizing element was to determine first, does it deoxidize? That is, does it adequately suppress porosity, and second, what are its side effects? Practically all the work was done on a low-alloy high-strength steel. Two criteria were used to determine deoxidizing powers: one indirect and the other direct. In the indirect method, a section of a standard casting was examined under the microscope for sulfide characteristics. If an element could not convert Type I to Type II sulfides, it was not regarded as a strong deoxidizer. For the direct test, a standard angle casting was made in green sand molds of various moisture contents and these castings were examined for pinhole porosity. Deoxidation with aluminum was the standard for comparison. Sulfur analyses on samples taken before and after the addition determined the desulfurizing ability of the material. Some general conclusions regarding deoxidation and desulfurization can be made, keeping in mind that general statements are not likely to be highly accurate for all conditions.

The matter of desulfurization by alloy addition can be disposed of very quickly. The only effective desulfurizers found were the rare earths, used in the form of misch metal. When enough is used to give appreciable lowering of the sulfur content, however, the steel is loaded with an undesirable type of inclusions. They seem to be a mixture of oxides, sulfides, and nitrides, like the Type IV inclusions of Figure 3. It is also expensive for this purpose. The only practical and economic way to desulfurize steel appears to be by treatment with a basic slag.

Manganese

Of all the materials classed as deoxidizers, manganese can be considered as the one most nearly indispensable. It is used in practically all steels, even when silicon is omitted. By itself, it is a relatively weak deoxidizer, but its presence makes silicon and aluminum better deoxidizers than they would be alone.[6, 7] It is a potent alloying agent and can improve the mechanical properties and the hardenability of a steel. But, it has one great virtue which would cause it to be used even in the absence of any other merit and that is its ability to form a stable, high-melting compound with sulfur.

When sulfur occurs in manganese-free iron, it forms FeS, which has a melting point of 1200°C, but FeS forms a eutectic with iron which freezes at 985°C and which contains about 30 pct S. During freezing of the iron, this eutectic is deposited in the primary grain boundaries and dendritic interstices as a pale, canary yellow film, which constitutes a continuous phase. A steel containing such a film formation will be extremely hot-short, and brittle when cold.

MnS is notably more stable than FeS, as will be noted in Table II, and when manganese is added to a steel in an amount in stoichiometric excess of the sulfur content, it virtually preempts the latter and forms MnS. An addition of four or five times the weight per cent of sulfur will insure that the sulfides formed will be predominantly MnS. The freezing point of MnS is 1610°C. It is soluble in liquid steel, though not so soluble as FeS, and does sometimes precipitate as the sulfide portion of a sulfide-

Table II. Free Energies of Formation of Some Metallic Sulfides at 1500°C

Reaction	ΔF at 1500°C
Fe (l) + 1/2 S_2 (g) → FeS	−16,220 calories*
Mn (l) + 1/2 S_2 (g) → MnS	−34,700 calories*
Ca (g) + 1/2 S_2 (g) → CaS	−85,600 calories*
1/2 Si (l) + 1/2 S_2 (g) → 1/2 SiS_2	+2,600 calories*
2/3 Al (l) + 1/2 S_2 (g) → 1/3 Al_2S_3	−13,800 calories*
Ti (s) + 1/2 S_2 (g) → TiS	−45,000 calories**
Ce (l) + 1/2 S_2 (g) → CeS	−98,000 calories†
2/3 La (l) + 1/2 S_2 (g) → 1/3 La_2S_3	−72,000 calories††

* *Basic Open Hearth Steelmaking.*
** Calculated from data in *Metallurgical Thermochemistry* by G. Kubaschewski and E. LL. Evans.
† "The Thermodynamics of Substances of Interest in Iron and Steelmaking. III Sulphides" by F. D. Richardson and J. H. E. Jeffes, *Journal*, Iron and Steel Institute (London), June 1952, pp. 165-175.
†† Calculated from data in *High Temperature Technology* by J. E. Campbell. John Wiley & Sons, Inc., p. 190, 1956.

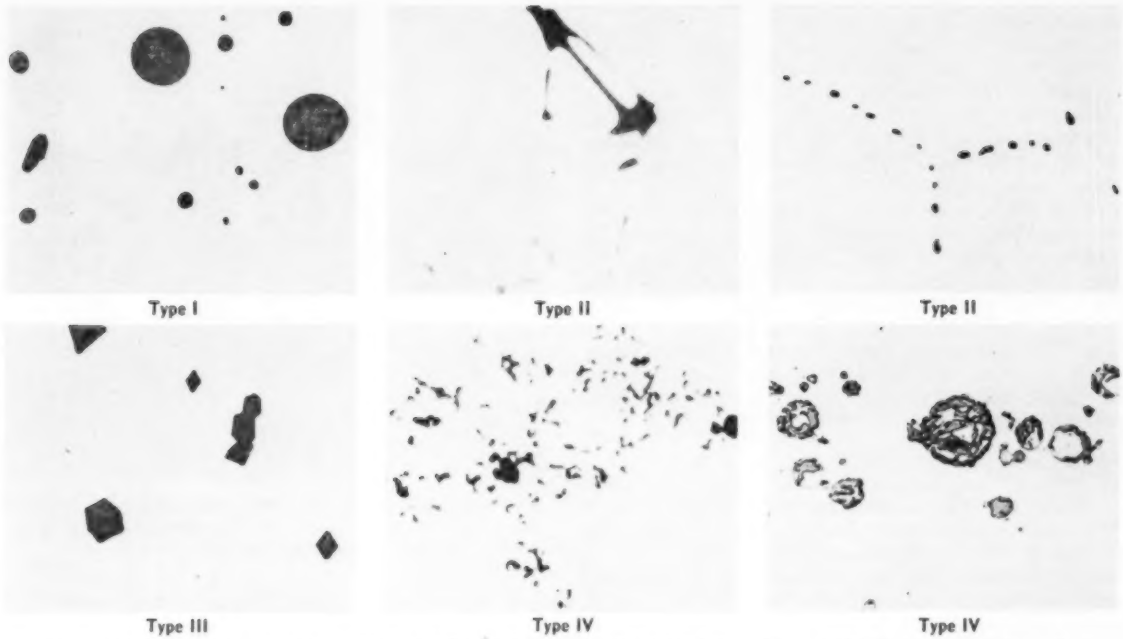

Fig. 3—SYSTEM USED FOR CLASSIFYING SULFIDE INCLUSIONS IN CAST STEEL: Type I, silicon deoxidation; Type II, critical additions of aluminum; Type III, excess aluminum over deoxidation requirements; Type IV, result of excessive use of misch metal. 500X.

iron eutectic, that is, as Type II inclusions. In normal steels containing 0.5 pct or more of manganese, the sulfides are essentially MnS whether they are classed as Type I, II, or III.

Aluminum

Aluminum is the next most widely used deoxidizer after manganese and silicon. It is not used as an alternative but as a supplement to the first two elements. It has a number of advantages to account for its wide use, such as low cost, ready availability, and stability in storage. It is one of the most powerful of the deoxidizers available, being rivaled only by zirconium. Because of its high potency as a deoxidizer, only small additions are required to give quite effective deoxidation. Such small additions, however, may lead to formation of Type II inclusions and result in poor ductility. This effect, which has been known for many years, has tended to give aluminum a bad reputation as a deoxidizer, even to the extent of calling it a poisoner of steel. It has been found, however, that an addition of aluminum somewhat greater than that required for complete deoxidation can cause a further change in the sulfides to the Type III (Fig. 3). This gives a considerably enhanced ductility as compared to the Type II inclusions but never quite so good as with the Type I. Such use of a judicious excess of aluminum has taken the onus from it to a considerable extent, but it is still regarded with suspicion in some quarters.

Unfortunately, the proven benefits of using an excess of aluminum have sometimes led to excessive use of aluminum, and when used in quantities which give residual contents above about 0.06 pct, a less favorable type of sulfide inclusion is formed, tending more to intergranular films than the ideal Type III inclusions.

Aluminum present in excess of that required for deoxidation tends to unite with any nitrogen present to form aluminum nitride (AlN). AlN has a limited solubility in solid steel and this solubility varies with temperature. As the temperature of a casting cools from the freezing point, the saturation with AlN will be reached at some temperature, usually above 1000°C, after which it will precipitate. The preferred location for such precipitation is primary grain boundaries, probably because both aluminum and nitrogen are present at these locations in the highest concentration as a result of dendritic segregation. When present in sufficient quantity, AlN produces great brittleness and low strength and causes the steel to break with an intergranular type of fracture often called the *rock candy* fracture.

Table III. Free Energies of Formation of Some Nitrides at 1500°C

Reaction	ΔF at 1500°C
Al (l) + 1/2 N_2 → AlN	−26,000 calories*
Ti (s) + 1/2 N_2 → TiN	−40,000 calories*
Zr (s) + 1/2 N_2 → ZrN	−42,000 calories*
B (l) + 1/2 N_2 → BN	−9,000 calories*
Ce (l) + 1/2 N_2 → CeN	−32,500 calories†
La (l) + 1/2 N_2 → LaN	−27,600 calories†

* J. Pearson and U. J. C. Ende: The Thermodynamics of Metal Nitrides and of Nitrogen in Iron and Steel, *Journal*, Iron and Steel Institute, September 1953.
† K. K. Kelley: *Contributions to the Data on Theoretical Metallurgy*, VIII The Thermodynamic Properties of Metal Carbides and Nitrides, Bureau of Mines Bulletin 407.

Titanium

Titanium may properly be considered as a superdeoxidizer for steel and is presently available either as fairly pure metal or as a constituent of some complex proprietary alloy. It is not quite so strong a deoxidizer as aluminum, but when added to steel in quantities greater than about 0.015 pct, Type II sulfides will be produced. Unlike aluminum, a further increase in the residual titanium does

not cause a change to Type III inclusions but produces a more extreme eutectic type of sulfide. As the titanium increases, the sulfides change from the characteristic dove gray color of manganese sulfide to a light tan color which is thought to be titanium sulfide. Such inclusions are shown in Fig. 4. Thus, the improvement in ductility that accompanies the formation of Type III sulfides cannot be accomplished with titanium.

Titanium nitrides are far more stable than aluminum nitrides and also seem to be completely insoluble in solidified steel. Because of this, any titanium present in excess of that required for deoxidation will combine with nitrogen and form nitrides which precipitate during freezing and appear as salmon- or pink-colored cubic crystals. Titanium also forms very stable and insoluble carbides, and the nitrides often contain some carbide.

Zirconium

Zirconium is at least as powerful a deoxidizer as aluminum and usually is used as a proprietary alloy but is becoming available in the form of pure zirconium metal. Like aluminum, small additions will cause conversion of Type I sulfides to Type II, and also like aluminum, a small excess will cause conversion to Type III sulfides. Zirconium is equally as good as titanium in forming stable insoluble nitrides which are precipitated as pink cubic crystals. Zirconium differs markedly from both aluminum and titanium in producing a higher content of oxide inclusions.

Zirconium, when added to a silicon deoxidized steel, forms crystalline zirconium silicates and zirconium oxide. As the residual zirconium is increased, the oxide content of the steel increases almost in proportion to the zirconium. Apparently the zirconium, after the initial deoxidation, increases the solubility of oxygen in steel. Thus, zirconium when used as a deoxidizer can give rather dirty steels, as illustrated in Fig. 5.

Misch metal

Although misch metal is a complex alloy, it will be spoken of in the singular. There are differences among the contained metals. For example: lanthanum appears to be much more active chemically than cerium, but as an addition to steel they both perform similarly and give similar effects. Misch metal is a strong deoxidizer and when added in certain amounts will produce Type II sulfides. Misch metal, however, is much too expensive to be used as a deoxidizer and is usually used only after an addition of aluminum which serves to protect it from loss by oxidation. The one great virtue of misch metal as far as a steelmaking addition is concerned is its ability to form sulfides which have relatively low solubility in molten steel. The value of misch metal, nevertheless, is not as a desulfurizer because there are cheaper and more efficient ways to desulfurize steel, if desulfurization is the objective.

The proper use of misch metal appears to be in adding a quantity that will just produce saturation of sulfur in the liquid steel at the liquidus temperature. In steels that do not contain misch metal, the saturation point for sulfur or where sulfides begin to appear occurs only after the steel is about 95 pct solidified and the sulfur has been heavily concentrated by dendritic segregation. When misch metal has been added in the appropriate quantity, the steel is saturated with sulfur at the start of freezing and sulfides begin to form immediately, thus the whole pattern of sulfide formation is changed and only sulfides of Type I are produced. Misch metal has the power to convert Type II or Type III sulfides, which have been formed by aluminum or zirconium additions, back to Type I sulfides. Unfortunately this is not true for Type II sulfides formed by titanium additions.

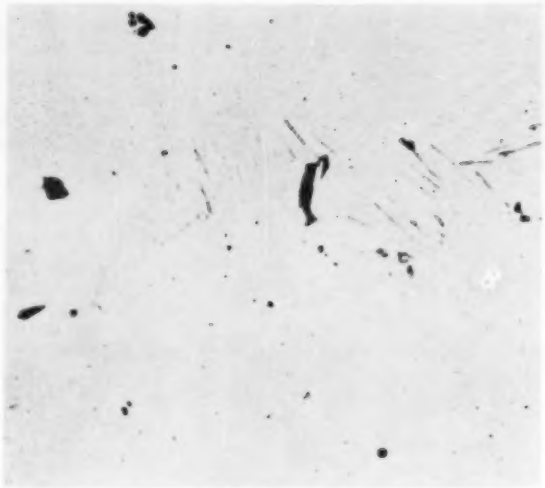

Fig. 4—Titanium sulfide inclusions in lamellar eutectic form produced by addition of 0.15 pct Ti. These sulfides are tan, in contrast to the dove gray of manganese sulfides.

The misch metal addition should be adjusted in proportion to the sulfur content of the steel. When used in excess of the ideal addition described above, it will form refractory sulfides and probably nitrides of a type tentatively designated Type IV inclusions and which are illustrated in the last two pictures of Fig. 1. Such inclusions make the steel unusually dirty and lower the ductility. The normal addition is in the range of 2 to 4 lb per ton.

Selenium

Selenium is an element very similar to sulfur in its chemical properties and cannot properly be designated as a deoxidizer, for the reason that it produces no deoxidation in cast steel. Its principal value in carbon and low-alloy steels is in preventing loss of ductility caused by deoxidation with such a strong deoxidizer as aluminum.

Selenium is soluble in liquid steel but precipitates as selenides when the steel freezes. These selenides are inclusions closely resembling sulfides, and when sulfur is also present, complex inclusions of sulfoselenides are formed. Thus, selenium influences the mode of formation of sulfides, and when an amount of aluminum has been added which would cause formation of Type II or Type III sulfides in the absence of selenium, the presence of a small amount of selenium will cause the sulfur to precipitate as sulfoselenides very similar to Type I sulfides. Such a steel will have ductilities that accompany Type I sulfides.

The improvement of ductility obtained by selenium is produced by reversion of Type II or III

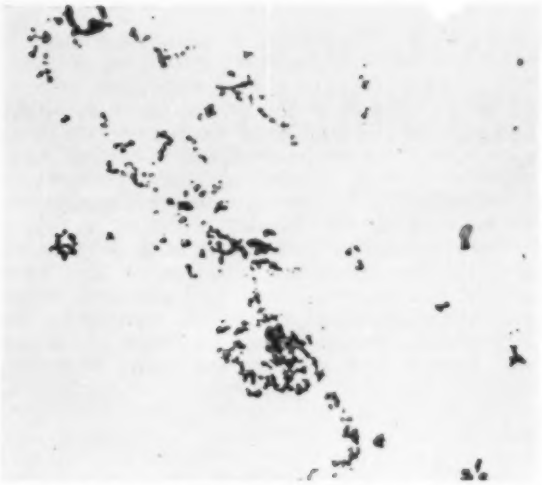

Fig. 5—Typical zirconium silicate clusters found in steels deoxidized with large amounts of zirconium. 500X.

sulfides to Type I sulfoselenides. Naturally, selenium can produce no improvements in ductility of a steel that would have Type I sulfides without its use. On the contrary, the ductility would be decreased because selenium would increase the total content of inclusions. In some cases it will even cause a decrease in ductility as compared to Type III sulfides.

Calcium, magnesium, sodium, barium, potassium, and lithium

The alkali and alkaline earth metals are all very active chemically and all form very stable oxides. From this standpoint they would seem to have a very high potential value as deoxidizers for steel, and numerous atempts have been made to use them for this purpose. All of them, however, have two properties in common which practically destroy their usefulness as deoxidizers for steel. They are virtually insoluble in either liquid or solid iron and all have boiling points considerably below the freezing point of steel.

Attempts to use potassium and lithium resulted in violent explosions on contact with the molten steel, which could endanger an operator. In addition, lithium produced extremely irritating fumes. Sodium and barium also caused violent reactions, but by alloying these materials with lead, which diluted them and increased their density, they could be used. Neither of these elements produced any deoxidation effects and neither of them removed any sulfur from the steel.

Magnesium also caused violent boiling in steel even when added in diluted form as an alloy with ferrosilicon. It produced no desulfurization but it did accomplish some definite deoxidation effects. Type II sulfide inclusions were produced with an addition of 3 lb per ton of magnesium-silicon alloy containing 70 pct Mg. Type III inclusions could not be obtained with greater additions. Even though magnesium produces some definite deoxidation effects, it is not considered a practical deoxidizer for steel, and any results it produces can be obtained more readily and cheaply with aluminum.

Calcium was given special consideration because of the rather wide spread use of calcium alloys in the deoxidation practices of cast steel. It was added as pure calcium metal, as calcium-silicon alloy, as calcium-manganese-silicon, and as calcium-lead alloy. Calcium produces the same violent agitation in the bath as does magnesium, because of its high vapor pressure, and its contact time with the steel is very short. Calcium did produce some definite, although slight, desulfurization when added to steel and it is more effective when used with a basic slag to prevent reversion of the sulfur. In two heats where calcium was added as a lead-calcium alloy, an addition of eight pounds of calcium per ton removed an average of 0.01 pct S. In other tests with smaller additions, no appreciable sulfur was removed. Thus, its efficiency as a desulfurizer for steel is so low as to make it quite unattractive for this purpose.

Repeated tests failed to show any deoxidation effect of calcium. When it was used as the only deoxidizer in addition to manganese and silicon, it gave no protection against pinhole porosity. This is in agreement with the findings of Lillieqvist.[10] Calcium added to silicon-killed steels containing Type I sulfides had no effect on the type of sulfide even when added to the extent of 8 lb per ton. The sulfides remained as Type I even though appreciable desulfurization was effected. When calcium was added to steels that had previously been deoxidized with ½ lb Al per ton and which contained Type II sulfides, the sulfides remained as Type II with additions up to 5 lb Ca per ton. Likewise, when enough aluminum had been added to produce Type III sulfides (2 lb per ton), they remained as Type III after a further addition of 5 lb Ca per ton.

In one case, samples for oxygen analysis were taken from a silicon-killed steel before and after treatment with 5 lb Ca per ton. The analyses showed 0.007 and 0.016 pct O_2, respectively. The apparent increase in oxygen is attributed to reoxidation from increased surface exposure to the air due to the violent agitation produced by the calcium addition rather than to any direct effect of calcium.

Calcium, as calcium-silicon or calcium-manganese-silicon, is widely used as an addition to casting steel and there is an equally widespread belief that it confers attractive improvements to the ductility of cast steel, but particularly when used after an aluminum addition. Although the opinion is held generally, supporting data are relatively scarce. A limited number of mechanical tests were made in the present study, but these did not show an outstanding benefit for calcium.

Most of the available information has been correlated by Shortsleeve and Hilty[13] who summarize this subject as, "Several investigators have shown that calcium, added along with aluminum, markedly improves the ductility of steel castings by minimizing intergranular sulfide inclusions."

The most recent as well as the most extensive data available appear to be those obtained by the Steel Castings Institute of Canada[14] on a series of 16 heats of low-alloy steels of varying compositions deoxidized with aluminum only and 16 heats of closely similar compositions deoxidized with aluminum plus calcium-manganese-silicon. Ductilities and V-notch Charpy data from these heats show that calcium did not affect the ductilities of these steels.

Complex deoxidizers

It has sometimes been considered advantageous to have deoxidizing alloys containing a number of elements, and a number of complex proprietary alloys have been produced. From the results obtained at Battelle, it was concluded that complex alloy additions could produce no effects which could not be produced by the simultaneous addition of these elements in separate alloys, when comparison is made on the basis of similar residual contents. Thus, there appears to be no magic in complex alloys but there are probable advantages, nevertheless. When one element is added to protect another and thus obtain higher recovery, it is advantageous to have them intimately associated as components of the same alloy. Also, in complex alloys, each element is in a more dilute form and thus is likely to give higher yields and efficiencies when added to the steel. Nevertheless, each element when added as a component of a complex alloy has the same effect as when added alone.

The ideal or universal deoxidizer

It has sometimes been thought that a deoxidizing alloy could be prepared which would be all things to all steels. To fulfill this function, it would have to give high protection against pinhole or other types of porosity when the steel is poured in green sand and even when the steel is high in nitrogen content. At the same time, it should leave the steel with high ductility, preferably with Type I inclusions, and should not produce any tendency to intergranular fracture when the steel is high in nitrogen. It is unlikely, however, that any one composition could be ideal for all steels.

The best combination appeared to be an alloy which used aluminum as the principal deoxidizer, misch metal to cause reversion to Type I sulfides, and zirconium to fix the nitrogen in harmless combination. These were dissolved in a ferrosilicon base that acted as a diluent and carrier. Such an alloy was completely stable when exposed to the atmosphere. With its use, the recoveries of misch metal were twice as great as when misch metal was used in undiluted form. Titanium was found to be just as efficient as zirconium in fixing the nitrogen as a stable compound, but when added in sufficient quantities to accomplish this result it produced Type II sulfides with resultant lowered ductility.

Tests with high-nitrogen steels

Ever since the work of Lorig and Elsea,[6] it has been known that a coarse intergranular type of fracture known as the *rock candy* fracture can be produced by the precipitation of aluminum nitride in primary grain boundaries of steel castings. The tendency of this precipitate to form is proportional to the product of nitrogen content and aluminum content. Such precipitates can often be prevented by fast cooling from the freezing temperature and are most pronounced after slow cooling, such as occurs in heavy sections. There is considerable evidence also that high nitrogen contents in steel exaggerate the tendency toward porosity and that aluminum is not always capable of preventing porosity in high nitrogen steels.

High nitrogen contents are often encountered in steel prepared for castings, particularly that which has been made in electric furnaces, and although it would be best to keep the nitrogen low, it is important to know how to avoid trouble from high nitrogen content. A series of heats were made in which nitrogen was purposely introduced to a content of 0.023 pct. These were deoxidized with an aluminum addition of 4 lb per ton and a keel block poured in a dry sand mold from each heat. They were cooled in a manner designed to develop intergranular fracture and coupons were fractured for examination. All had pronounced integranular fracture and all were notably porous.

The remaining portion of each of these heats was then further deoxidized and another keel block poured. One was deoxidized with additional aluminum and misch metal. Neither the porosity nor the intergranular brittleness was improved. The second was treated with an alloy containing aluminum, misch metal, and a small amount of titanium. In this case, the titanium was effective in eliminating porosity but not in preventing intergranular fracture. The third one was treated with an alloy containing aluminum, misch metal, and a larger amount of titanium. In this case, both the porosity and the intergranular fracture were eliminated. This steel, however, had Type II sulfides. The fourth was treated with an alloy containing aluminum, misch metal, and zirconium, and both the porosity and intergranular fracture were eliminated and the steel had Type III inclusions.

This seems to be evidence that high nitrogen contents can cause troublesome porosity that aluminum is powerless to prevent. It is also evident that misch metal cannot cure intergranular fracture. Titanium and zirconium are equally able to prevent both porosity and intergranular fracture resulting from high nitrogen contents. When enough is added for this purpose, however, the titanium produces Type II sulfides, while the zirconium will provide Type III sulfides. If sufficient misch metal is used with zirconium, Type I sulfides will result, but not when titanium is used. On the other hand, the use of zirconium is probably not warranted when the nitrogen is so low as to cause no trouble, because it tends to produce a dirty steel. The use of misch metal is largely futile unless enough is added to produce Type I sulfides.

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PRACTICAL ECONOMICS FOR STAINLESS STEEL MELTERS

Cost savings in electric furnace steelmaking can be realized by paying attention to the correct material charge and by adopting better melting practices to give improved yields.

by R. B. Shaw

REDUCTION of ingot costs by a careful appraisal of all materials charged into an electric furnace has failed to excite the imagination and ingenuity of operators in the past, due to the fact that little has been written on the subject. Nevertheless, the area of material cost in the ingot constitutes from 70 to 85 pct of the total cost, depending on the type of stainless. The balance of the cost is known as operating or conversion costs. This is the cost of converting the materials into usable ingot form and will be described in more detail below. Since the materials charged constitute the major part of an ingot cost and so many types of materials are required to produce an ingot, it would seem logical that both the tonnage material items as well as the high priced ones should be examined first.

Those who melt stainless steel use their own plant revert scrap and make outside purchases of stainless scrap as well. Stainless scrap used can constitute from 35 to 80 pct of the charge, depending on such factors as availability, cost, physical condition, and analysis. Besides low-phosphorus carbon or low-alloy scrap, the other items used are ferro-chromium, both high- and low-carbon, manganese, nickel, and silicon alloys containing various percentages of chromium or manganese.

To effectively reduce material costs, the operator should consistently calculate the cost of various material balances, making use of all the talent and know-how at hand. In this way, the most economical material balance consistent with good operating costs can be achieved.

Variables affecting the maximum or B/E to pay for 430 scrap

Reference to Table I indicates that in order to use purchased 430 scrap to advantage it must be so priced that the heat in which it is used (Heat B) does not cost more than the standard or reference heat (Heat A). In fact, Heat B must cost less in order to justify the use of purchased 430 scrap.

To do this, the requirements are as follows: The material cost of the standard Heat A, in which only plant revert 430 scrap is used, minus the material cost of Heat B, where both revert and purchased 430 scrap is used, must equal zero for the determination of the maximum or B/E amount to pay. The individual cost items, $(\Delta c_2 \ldots \Delta c_8)$ in Heat B may be zero, negative, or positive depending in what direction the cost varies as determined by the magnitude of $(\Delta p_2 \ldots \Delta p_8)$. Therefore, $C_t - (C'_t + \Delta C_t) = 0$. Since $C'_t = c_2 + C_t$, then by substitution, $C_t - (C_t + c_2 + \Delta C_t) = 0$. As a result, $c_2 = -\Delta C_t$ or the maximum price to pay for p_2 lb of 430 scrap. In other words, there must be a sufficient cost decrease in the total of items $(\Delta c_3 \ldots \Delta c_8)$ to offset the cost of using p_2 lb of purchased 430 scrap at a cost of c_2 dollars.

One satisfactory method of calculating a price to pay for 430 scrap is as follows: By the experience gained in melting and blowing stainless heats, it has been found that in order to blow a heat to 0.04 pct C, for example, it is necessary to add enough gaseous oxygen to theoretically oxidize 50 pct of the chromium in the initial charge. This would apply to large furnaces at an oxygen rate indicated elsewhere in the text. Where melt carbon is higher than 0.15 to 0.20 pct due to the use of high Fe-Cr, it has been found that each pound of additional carbon requires about 16 cu ft O_2. It must be mentioned that the chromium is singled out to be oxidized at a certain percentage to aid the heat calculator and also because other items used in the heat can easily be related to it. It is recognized that the chromium, in reality, is not oxidized 50 pct and that the other reducible oxide metals (Fe, Mn.) are also oxidized.

Calculation of correct price to pay for 430 scrap

It is advisable to refer to Table II and the appendix for clarity in the use of the constants shown here. Suppose it desired to use, in addition to revert stainless scrap, purchased 430 scrap that contains 16.5 pct Cr. Let P (same as p_2 of Table II) equal the amount used in the heat. Bearing in mind that 50 pct of the chromium in the scrap will be theoretically oxidized, the calculation of a maximum price to pay for 430 scrap is as follows:

$(0.165\ P/2)\ (0.404/0.43)$	$= 0.0775\ P$ lb Fe-Cr-Si required for P.	(1)
$0.0775\ P\ (0.56)$	$= 0.0434\ P$ metallic wt of the Fe-Cr-Si.	(2)
$0.0775\ P\ (0.39) + 0.1650\ P$	$= 0.1953\ P$ lb less Cr to use as low C-Fe-Cr.	
$0.1952\ P/0.6475$	$= 0.3015\ P$ lb less low C-Fe-Cr to use.	(3)
$P + 0.0434\ P - 0.3015\ P$	$= 0.7419\ P$ lb less low Phos C scrap to use.	(4)
$0.0775\ P\ (1.2)$	$= 0.093\ P$ lb lime required.	(5)
$(0.165\ P/2)\ (5.58)$	$= 0.4607\ P$ cu ft O_2 required.	(6)

The costs of the above items are:

$0.0775\ P\ (0.167)$	$= +\$.01294\ P$ (cost of item (1) above).
$0.3015\ P\ (0.2352)$	$= -0.07091\ P$ (cost of item (3) above).
$0.7419\ P\ (0.023)$	$= -0.01706\ P$ (cost of item (4) above).
$0.093\ P\ (0.009)$	$= +0.00084\ P$ (cost of item (5) above).
$0.4607\ P\ (0.165/100)$	$= +0.00076\ P$ (cost of item (6) above).

$$c_2 = \Sigma P = -\$.07346\ P \qquad [1]$$

If $P = 1$ lb, then $c_2 = \$.07346$ per lb scrap. \$.0734 x 2240 lb = \$164.42 per gross ton as the maximum price to pay for 430 scrap. In this case, there was no change in the use of high C-Fe-Cr through the use of purchased 430 scrap. In other words, $\Delta p_2 = 0$.

It would be very unlikely that a melter, for ex-

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ample, would increase the amount of high C-Fe-Cr at the same time additional 430 scrap was being used. However, he might choose to decrease the chromium in the high C-Fe-Cr by the same amount of the additional chromium in the purchased 430 scrap. If so, then Δp_3 decreases as the use of p_3 increases. Reference to the analysis and cost of the high C-Fe-Cr in Table II and the appendix, the calculation of the effect of a decrease in Δp_3 is computed exactly as was done when P lb of purchased 430 scrap was used. If Δp_3 represents the change or decrease in the use of high C-Fe-Cr, then

$$c_3 = -\$.07346\,P - (-\$.04117\,\Delta p_3). \qquad [2]$$

According to Eq. 2, if 10,000 lb purchased 430 scrap was used in a 50-ton heat, the high C-Fe-Cr would have to be decreased 4645 lb to keep the pounds of chromium in the initial charge the same. This would make the maximum price to pay for 430 scrap $121.63 per gross ton.

It is interesting to note that the unit costs of the individual raw material items greatly influence the *B/E* point to pay for 430 scrap. If the low C-Fe-Cr used in the calculation of the scrap price was $.02 per lb Cr higher in cost than the example given, the *B/E* would be moved from $164.42 to $182.34 per gross ton. However, items that may not change in magnitude with the use of purchased 430 scrap, such as revert 430 scrap or high C-Fe-Cr, do not influence the *B/E* point. Every furnace operator is fully aware, however, that the reverted scrap price as determined by the accounting dept. should be reasonably below the market price of 430 scrap to obtain low ingot costs.

Fig. 1 shows the economy of using purchased 430 scrap as well as showing the *B/E* point being independent of the amount of purchased scrap used. At the *B/E* point of $164.42 per gross ton, there is no savings by using purchased 430 scrap. Less than the *B/E* point, there is considerable savings. Fig. 2 shows how the cost of low-phosphorous carbon scrap influences the maximum amount to pay for 430 scrap. In this curve all other items of raw material in the heat have been kept constant in weight and unit cost. The analysis of high C-Fe-Cr in addition to its market price can be used to advantage in lowering ingot costs, mainly due to iron crediting, as is shown in Fig. 3. Besides direct savings, there are several indirect savings by using high C-Fe-Cr containing a high percentage of iron; namely, the time and expense of not having to unload the same iron complement as low-phosphorous carbon scrap and the freight savings, since Fe-Cr is priced fob, customer's plants.

Oxidizing period

When the most economical raw material balance has finally been decided, the main function of the oxygen blow is to oxidize the melt carbon to a safe level without oxidizing any more of the Cr, Fe, and Mn than is necessary. How to do this has been the subject of a number of papers in the past several years, mainly by associates of Union Carbide Metals Co.[1] Fig. 4 shows that when the percent oxidation of the chrome in the initial charge can be decreased, there is a substantial savings to be had even without any improvement in chromium yield. However, with an improvement in Cr yield the joint savings are considerable.

A number of 10-ton heats were made to determine the effect of the oxygen rate on the retained chrome in the bath, as well as to ascertain any improvement in Cr yield. The charges were completely melted and mixed before the metal samples and temperatures were taken. The percent chrome oxidation, pounds Fe-Cr-Si, and burnt lime needed were determined before the heats were melted according to the method described in the appendix. From the results shown in Table III there is an improvement in chrome yield with an increase in blow rate.

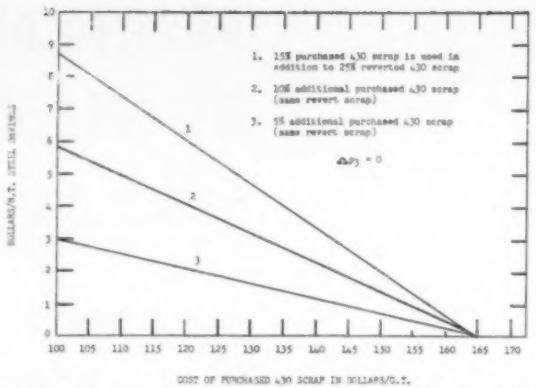
1. 15% purchased 430 scrap is used in addition to 25% reverted 430 scrap
2. 10% additional purchased 430 scrap (same revert scrap)
3. 5% additional purchased 430 scrap (same revert scrap)
ΔP = 0
1
2
3
100 105 110 115 120 125 130 135 140 145 150 155 160 165 170

Fig. 1—Savings per ton steel vs price paid for outside purchases of 430 scrap.

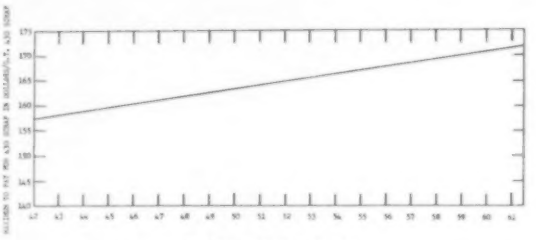

Fig. 2—Effect of price of low-phos C scrap on price of 430 scrap.

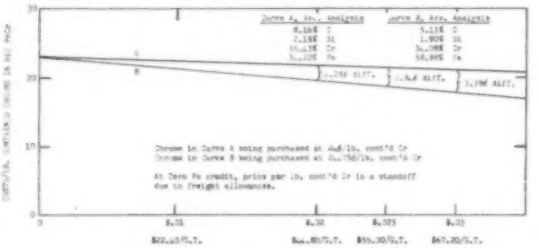

Fig. 3—Effect of crediting Fe in high C-Fe-Cr to price per lb of contained chrome.

Table I. Example of Materials Used for Calculation of Maximum Price to Pay for 430 Scrap*

	Material	Std Heat A		Heat B	
		Metallic Wt	Cost of Material	Metallic Wt	Cost of Material
1.	Revert 430 Scrap	p	c	p_1	c_1
2.	Purchased 430 Scrap	—	—	p_2	c_2
3.	High-C-Fe-Cr	p_3	c_3	$p_3 + \Delta p_3$	$c_3 + \Delta c_3$
4.	Low Phos C Scrap	p_4	c_4	$p_4 + \Delta p_4$	$c_4 + \Delta c_4$
5.	Fe-Cr-Si	p_5	c_5	$p_5 + \Delta p_5$	$c_5 + \Delta c_5$
6.	Low-C-Fe-Cr	p_6	c_6	$p_6 + \Delta p_6$	$c_6 + \Delta c_6$
7.	Burnt Lime	p_7	c_7	$p_7 + \Delta p_7$	$c_7 + \Delta c_7$
8.	Gaseous Oxygen	p_8	c_8	$p_8 + \Delta p_8$	$c_8 + \Delta c_8$
9.	Total	P_t	C_t	$P'_t + \Delta P_t$	$C'_t + \Delta C_t$

* Cost of Heat A − Cost Heat B = 0 for Maximum to pay for 430 Scrap.

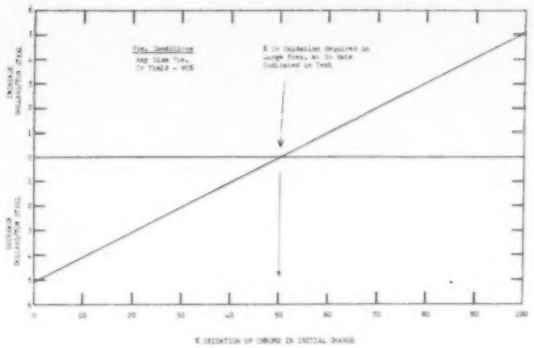

Fig. 4—Effect of Cr oxidation on cost of steel.

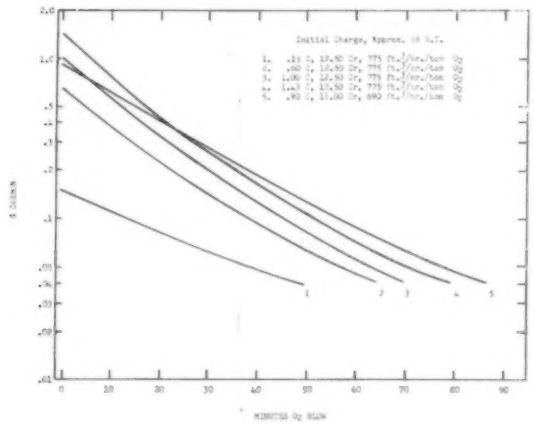

Fig. 5—Pct carbon vs minutes oxygen blow.

In larger furnaces at Brackenridge, blow rates are considerably less than for 10-ton furnaces. At the blow rates indicated in Fig. 5, it is necessary to oxidize 50 pct of the Cr to obtain approximately 0.04 pct C. Comparing curves 2, 3, and 4 with curve 1, it may be shown that the extra carbon at meltdown requires approximately 16 cu ft O_2 per lb C. Curve 5 cannot be directly compared to curve 1 because of the different blow rates, but it does indicate that a lower oxygen rate prolongs the blowing time as it does in small furnaces.

In the oxidizing period the most important single item to consider in minimizing material costs is the final temperature obtained after the oxygen blow. It is this maximum operating temperature that ultimately defines the lowest cost raw materials that may be used in the initial charge. The Cr-C-Temp curves of Hilty may be used in a practical manner to aid the melting operator in knowing what his final temperature is, but the maximum workable temperature that can be tolerated in a furnace can be found only by lengthy experiments, since furnace refractory construction as well as daily furnace maintenance of banks, bottom, and side walls differs from plant to plant. Once this has been established, however, there appear to be several ways in which a high maximum temperature can be attained; namely, 1) by melting more completely and to a higher starting temperature than normal before beginning the oxygen blow; 2) by using a high-C-Fe-Cr that contains enough carbon and silicon which, when oxidized, will provide additional heat; 3) by increased blow rates; or 4) by a combination of the latter two methods.

One other method worth considering is melting to less than normal. By doing this, additional high-C-Fe-Cr can be used. Then, with a high-oxygen blow rate coupled with the heat developed from the oxidation of the extra chromium, carbon, and silicon in the charge, the same maximum temperature can be obtained. Despite a longer blow time and a somewhat larger slag volume, such a charge can result in an extremely low cost ingot. However, with charges that result in larger slag volumes that may possibly decrease the tap weight or tons per hr, the variable portion of operating cost must be properly fitted into the equation for minimum costs. On the other hand, by making use of the chemical heat during oxidation of chromium, carbon, and silicon, and by having a furnace on load for less time before the oxygen blow, consideration must be given to the effect of electric power costs when less energy is consumed, and especially the demand charges where a number of furnaces are operating.

Reduction period

In the reducing period which immediately follows the oxidizing period, cool-off scrap, low-C-Fe-Cr and a suitable low-C-Cr alloy containing silicon are added to the high temperature bath. In any study of stainless steel melting economics it becomes apparent that the amount of cool-off scrap is perhaps one of the prime factors in lowering ingot costs. The use of a substantial amount of cool-off scrap is dependent on: 1) availability; 2) physical condition; 3) temperature of the bath prior to its use; 4) chemistry of the scrap; and 5) the amount of other ferro alloys added at the same time.

Equally important in lowering ingot costs is the choice of the proper chrome silicide for reduction. Fig. 6 shows how the analysis and cost of the chrome silicide used in the reduction mix affect the cost of stainless steel. The open circles appearing on curves 1-9 inclusive indicate how the fluctuation in the market price of the various silicides prior to October 1958 influenced ingot costs. Reference to Table IV shows the type or types of Fe-Cr-Si used in the reduction mix, as well as the market price.

Prior to June 2, 1958, the Cr in regular Fe-Cr-Si sold for 27.5¢ and the Si for 14.20¢. Then on June 2, the price was lowered to 24.25¢ (Cr) and 13.75¢ (Si). The effect on ingot costs can be seen by referring to curves 1 and 2. Lowering the silicon cost reduced the ingot costs 26¢ per ton, whereas the decrease in the chrome cost reduced the ingot costs, $1.70 per ton or a net effect of $1.96 per ton steel. These two curves represent, in general, the gain enjoyed by those companies which used regular Fe-Cr-Si. However, the small minority of steel makers who were using a Fe-Cr-Si analyzing 48 pct Cr and 34 pct Si were already $2.50 per ton below those using regular Fe-Cr-Si, so despite the June 2 reduction in Fe-Cr-Si prices, the use of the 48/34 alloy still gave an advantage of about $1.85 per ton steel over those who clung to regular Fe-Cr-Si. This is shown in curves 3 and 5. Curve 4 represents the conditions in effect prior to June 2. Here it can be seen that a blend of two types of Cr silicide was somewhat cheaper than that shown for curve 3, and considerably cheaper than that shown

on curve 1. Curves 6-9 inclusive represent the effect of blending two types of chrome silicide on the ultimate ingot costs. Curves 2, 5, 6, 7, 8, and 9 can all be compared directly, since the market price of Fe-Cr-Si did not change from June 2 to October 1, 1958.

On October 1, 1958 the chrome silicides were again changed in price. The prices in effect as of now are those in Table II. Fig. 7 shows the decrease of ingot costs by blending various silicon alloys when compared to using only regular Fe-Cr-Si in the reduction mix. The Cr/Si ratio of Fig. 7 refers to the Cr/Si ratio of the blend used. For example, using only regular Fe-Cr-Si as the reducer, the ratio would be 39 pct Cr/43 pct Si or 0.91—the intersection of curves 1, 2, and 3 with the ordinate. As indicated in Table V, as this ratio increases it is necessary to blend up by using a higher Cr/Si alloy along with regular Fe-Cr-Si. It is problematical whether the reduction can be successfully done beyond a ratio of 2.39 (55/23). This can be achieved as shown in Fig. 7 by four blend choices. The Cr/Si ratio in the reduction is dependent on the amount of high-C-Fe-Cr and alloy scrap used in the initial charge. Also, since increased blow rates decrease the required amount of Fe-Cr-Si, there is a possibility that under these conditions richer blends can be better used.

Finishing period

The final additions made to a heat of stainless consist mainly of low C-Fe-Cr, electrolytic or Fe-Mn, and 50 or 75 pct Fe-Si. Most of the time some chromium and silicon are needed. Fig. 8 shows the economy of using one of the Cr silicides as the source of all or part of the Cr and Si required. Suppose, for example, in making a 50-ton heat of type 302 stainless that 250 lb Si (0.25 pct) and 1500 lb Cr (1.50 pct) are needed for the final additions, plus whatever other alloys are required. Since this represents a Cr/Si ratio of 6/1, reference to Fig. 8 shows that the most economical Cr silicide to use would be that shown on curve 4, although there is a savings with any of the silicides; however, using the 50/10 alloy results in a savings of 3.94¢ per lb Cr added or $1.18 per net ton steel.

Operating costs

Operating costs or the cost of converting the raw materials and fluxes used in making steel into ingot form may be subdivided into four primary elements

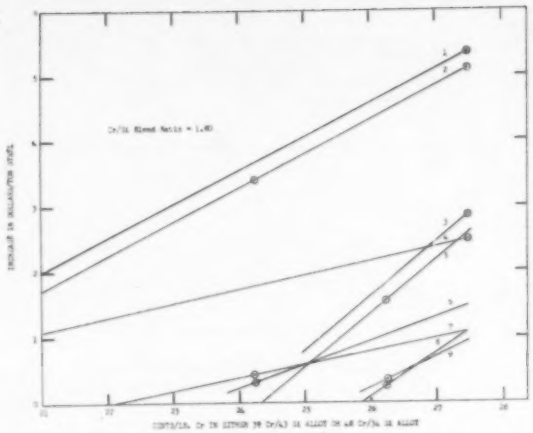

Fig. 6—Influence of past prices of Fe-Cr-Si on cost of steel.

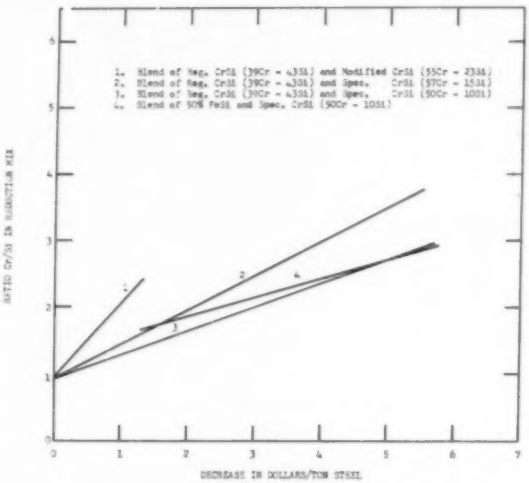
1. Blend of Reg. CrSi (39Cr - 43Si) and Modified CrSi (55Cr - 23Si)
2. Blend of Reg. CrSi (39Cr - 43Si) and Spec. CrSi (57Cr - 15Si)
3. Blend of Reg. CrSi (39Cr - 43Si) and Spec. CrSi (50Cr - 10Si)
4. Blend of 50% FeSi and Spec. CrSi (50Cr - 10Si)
DECREASE IN DOLLARS/TON STEEL

Fig. 7—Effect of Cr:Si ratio of blended mix on cost of steel.

of cost: 1) fixed operating costs; 2) operating costs that vary with hours; 3) costs that vary with net tons produced; and 4) electric power cost.

All of these, except fixed operating cost, represent areas of cost over which the melting supervisor may have a direct means of control.

The first group of costs known at fixed costs make up such items as depreciation on buildings and

Table II. Cost and Analysis of Raw Materials

Material	Approximate Composition, Pct				Market Price ¢ Per Lb	Adjusted Price ¢ Per Lb
	Cr	C	Si	Fe		
High-C-Fe-Cr	35.52	6.75	2.50	54.23	26.50 (Cr)	24.79 (Cr)
High-C-Fe-Cr	34.08	5.13	1.90	58.88	24.75 (Cr)	23.16 (Cr)
High-C-Fe-Cr	35.43	8.16	2.18	34.22	24.00 (Cr)	23.02 (Cr)
Fe-Cr-Si	39.00	0.05	43.00	17.00		
					28.25 (Cr)	26.70 (Cr)
					14.60 (Si)	14.60 (Si)
Fe-Cr-Si	55.00	0.05	23.00	21.00		
					32.25 (Cr)	31.60 (Cr)
					14.60 (Si)	14.60 (Si)
Fe-Cr-Si	58.00	0.05	15.00	26.00		
					32.25 (Cr)	31.60 (Cr)
					14.60 (Si)	14.60 (Si)
Fe-Cr-Si	50.00	0.05	10.00	39.00		
					32.25 (Cr)	31.60 (Cr)
					14.60 (Si)	14.60 (Si)
Low-C-Fe-Cr	64.75	0.02	1.25	33.00	36.75 (Cr)	36.32 (Cr)
Low Phos C Scrap					2.30	
Burnt Lime					6.90	
Oxygen					16.50 per 100 cu ft	

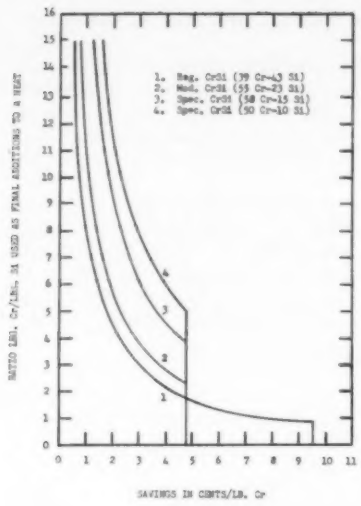
1. Reg. CrSi (39 Cr-43 Si)
2. Med. CrSi (55 Cr-23 Si)
3. Spec. CrSi (58 Cr-15 Si)
4. Spec. CrSi (50 Cr-10 Si)
RATIO LBS. Cr/Lbs. Si USED AS FINAL ADDITION TO A HEAT
SAVINGS IN CENTS/LB. Cr

Fig. 8—Economy of using Cr-Si as a final addition to a heat of stainless.

equipment, taxes, insurance, and even the melting superintendent's salary. Also included in this group are the fixed portions of semi-variable costs such as supervision, clerks, and certain elements of productive labor. Semi-variable costs usually do not decline in direct relation to operations, therefore, within normal areas of operation, they are definitely fixed.

During periods of reduced operations, this type of cost results in a high ingot cost and less profits. In periods of high activity, fixed elements are usually overlooked because everyone is intrigued by the high levels of production. However, regardless of high or low activity, they must be absorbed into the ingot cost as well as the final product. In fact, in any analysis dealing with expansion of electric furnace facilities, it may be that you can break even at 5000 net tons, whereas with new facilities you must produce 10,000 net tons to break even. Fundamentally, there must be a market available for additional capacity to realize additional profits. In short, volume is the only primary element to initiate a reduction in costs within this area since the total dollars remain the same whether the activity is high, low, or zero.

It becomes apparent, and particularly as activity declines, that the maximum effort must be within those areas of out-of-pocket cost, namely, tonnage and hourly costs.

Within tonnage costs are those costs that bear no relationship to the net tons steel produced per hour. This is important because cost reductions concerned with increased furnace efficiency usually have no effect on this group of expenses, and so are kept as a separate cost function. Such items appearing under the heading of tonnage costs are ingot molds, furnace rebuild, hot tops, teeming supplies, oxygen, and so on. In other words, these expenses are incurred only when steel is produced and the unit cost usually remains constant regardless of the net tons per hour. For example, when a 10,000 lb ingot is poured, it will cost the same per ton for the mold usage, stool usage, and hot tops whether the heat may have been produced at 5 or 10 tons per hr. This does not mean, however, that cost control does not exist within tonnage costs, for within tonnage costs the greatest amount of waste and carelessness can frequently occur among furnace and ladle crews. Also, high costs can exist due to the lack of improved material handling and storage methods.

It is conceivable that tonnage costs could increase, but may bring about improvements in yield in the slabbing operation which would result in an overall lower cost of the final product. Thus, the electric furnace operator must be open-minded and strive to be more than just concerned with his own departmental costs.

The last main cost segment, exclusive of electric power, is hourly costs. These costs are affected primarily by furnace efficiency and net tons produced per hour, and are easily recognized through a lower

Table III. Effect of Oxygen Rate on Several Dependent Variables

Metallic Charge, net tons	9.35	9.35	9.35	9.35
ITC Temp. before O_2, °F	2740	2750	2780	2770
Pct Melted before O_2	100	100	100	100
Melt Cr, Pct	11.85	12.00	11.90	11.70
Melt C, Pct	0.60	0.48	0.61	0.56
Minutes O_2	43	25	13	8
Pressure, Psi	35	50	75	90
Lance Diam, in.	1	1	1	1
O_2 rate per hr per net ton	**1540**	**2180**	**3370**	**4010**
Pct Cr before O_2	4.60	5.66	7.70	8.60
Pct C after O_2	0.01	0.035	0.032	0.032
Avg Pct Cr Yield	87.7	91.9	92.8	100
Pct Cr Oxidation	65	55	38	26
Regular Fe-Cr-Si, Lb	1400	1180	850	575
Burnt Lime, Lb	1680	1425	1025	700
No. Heats	4	5	7	4
Type Steel	304	304	304	304

Table IV. Cost of Various Cr Silicides

Curve	Reduction Mix	Market Price** ¢ Per Lb
1	Fe-Cr-Si(39 Cr-43Si)	14.20 (Si) Cr price (Fig. 7)
2	Fe-Cr-Si (39/43)	13.75 (Si) Cr price (Fig. 7)
3	Fe-Cr-Si (48Cr-34Si)	14.20 (Si) Cr price (Fig. 7)
4	Blend (39/43 and 55/23)	39/43, same as curve 1 55/23; 29.50 (Cr), 14.45 (Si)
5	Fe-Cr-Si (48/34)	13.75 (Si) Cr price (Fig. 7)
6	Blend (39/43 and 57/15)	13.75 (Si), Cr price (Fig. 7) 57/15; 29.25 (Cr), 13.75 (Si)
7	Blend (39/43 and 55/23)	13.75 (Si), Cr price (Fig. 7) 55/23; 28.25 (Cr), 13.75 (Si)
8	Blend (48/34 and 57/15)	48/34; 13.75 (Si), Cr price (Fig. 7) 57/15; 13.75 (Si), 29.25 (Cr)
9	Blend (48/34 and 55/23)	48/34; 13.75 (Si), Cr price (Fig. 7) 55/23; 13.75 (Si), 28.25 (Cr)

* The two types Fe-Cr-Si are blended to give a Cr/Si ratio of 1.80.
** Market prices in effect prior to October, 1958.

Table V. Percent Si in Reduction from Various Cr Silicides

Ratio Cr/Si	Method Number* 1 Pct	2 Pct	3 Pct	4 Pct
1.60	53.3 (A)	76.0 (A)	83.1 (A)	83.1 (E)
	46.7 (B)	24.0 (C)	16.9 (D)	16.9 (D)
1.80	40.0 (A)	69.2 (A)	78.2 (A)	78.2 (E)
	60.0 (B)	30.8 (C)	21.8 (D)	21.8 (D)
2.00	26.4 (A)	62.2 (A)	73.3 (A)	73.3 (E)
	73.6 (B)	37.8 (C)	26.7 (D)	26.7 (D)
2.39	— (A)	48.7 (A)		
	100 (B)	51.3 (C)		
3.00		27.6 (A)	48.9 (A)	48.9 (A)
		72.4 (C)	51.1 (D)	51.1 (E)

* Method 1 Blend of Regular Cr-Si (A) and 55Cr/23Si alloy (B)
2 Blend of Regular Cr-Si (A) and 57Cr/15Si alloy (C)
3 Blend of Regular Cr-Si (A) and 50Cr/10Si alloy (D)
4 Blend of 50 pct Fe-Si (E) and 50Cr/10Si alloy (D)

ingot cost when efficiency is high and productive labor is well utilized. Within this cost area, the total variable expense elements are furnace crews, stocker and ladle crews, crane operators, and maintenance labor, combined with the variable portion of semi-fixed expenses such as supervision and clerks, chemical laboratory costs, and yards and railways. These costs will ordinarily decrease in direct relationship to hours of furnace activity and will be zero at zero activity level.

Dollar cost reductions that can be brought about by increased net tons per hour on large furnaces as compared to smaller units are probably of greatest interest in hourly costs. Suppose, for example, the variable hourly cost to operate a large furnace making 12 tons per hr is $115 per hr; while on a small furnace making 1.2 tons per hr it is $50 per hr. If each furnace increased its tons per hour 10 pct, giving 13.20 and 1.32 tons per hr for the two furnaces, the cost reduction would be:

Small furnace: 20 turns per week

1.20 tons per hr x 693 hr per mo = 831.60 tons per mo
1.32 tons per hr x 693 hr per mo = 914.76 tons per mo
$50 per hr x 693 hr per mo = $34650/831.6 = $41.67 per ton
$34650/914.76 = $37.88 per ton
$41.67 − $37.88 = $3.79 per ton decrease
1.32 tons x $3.79 = $5.00 per hr decrease in variable hourly cost
$5.00 x 693 hr per mo = $3465 monthly decrease in costs.

A similar calculation will show that at the end of an accounting month, the total dollar savings will be more than twice as great in the larger furnace ($7965); however, as shown for the small furnace, there is still a substantial decrease in costs. The two examples merely point out in elementary fashion the behavior of variable hourly costs.

Electric power cost is the one remaining element in the breakdown of an electric furnace ingot cost. Here the kw-hr consumed per net ton and the cost per kw-hr are the cost factors to consider. In most cases, they are dependent on the power company rate schedules. The monthly billed cost of power consists of three subcharges: energy, fuel adjustment, and demand. The consumption of kilowatt hours is charged in a manner similar to home consumers. The fuel adjustment is based on the increase in the cost of coal above a base period used to establish a rate per kw-hr. At a reasonably efficient operation there is not much the furnace operator can do about saving kilowatt hours.

To discourage uneven use of power, the power companies have built a demand charge into their price policies. In this way plants which make no attempt to control peak loads are charged for this inadequacy. At Brackenridge, the rate is so constructed that about $1.64 per mo is saved for every kilovolt-ampere reduction based on the average of the four or five weekly computed 15 min peak demands for that month.

Some companies control peak loads by automatic demand limiters, while others do their own regulating by attention-getting devices such as the blowing of horns or by careful regulation of operations. Other companies with lower levels of volume choose to operate their electric furnaces at night during the off-peak period and the rolling or finishing departments during the day. An excellent paper has been written by C. A. Scammon[2] in which he describes a demand-limiting system which has saved up to $20,000 per mo.

Conclusion

A cost savings can be realized by paying careful attention to the correct material charge and the adoption of better melting practices to attain improved yields.

The four primary elements of operating or conversion cost are closely related. With one affecting the other in many instances in terms of cost reduction, each must be examined individually to understand and appraise its influence on the ultimate ingot cost.

To do this, effective dollar budgets must be established and maintained, and time and usage standards developed and understood. These then become the index for measuring performance and to point up areas where costs are out of control. With these tools in the hands of the operator, the results can be an effective program of cost control.

Appendix

Sample calculation of several of the constants used in text

Fe-Cr-Si and oxygen required:

$$2Cr_2O_3 + 3Si \rightarrow 4Cr + 3SiO_2$$
$$(84) \qquad (208)$$

1 lb Cr requires 84/208 or 0.404 lb Si
1 lb Cr requires 0.404/0.43 or 0.94 lb Fe-Cr-Si
1 lb Cr requires 0.4615 lb O_2
1 lb Oxygen occupies 12.10 cu ft @ 70°F − 1 atm
1 lb Cr requires 5.58 cu ft O_2 @ 70°F − 1 atm

Adjusted cost of high-C Fe-Cr:

35.52 pct Cr x 2000 lb = 710 lb Cr
710 lb Cr x 26.50¢ (market) = $188.15 cost Cr (a)
Assumed Barge Allowance = $12.11 per net ton material (b)
(a-b)/710 lb = 24.79¢ per lb Cr
24.79¢ x 0.3552 = 8.805¢ per lb material

Adjusted cost of regular Fe-Cr-Si:

39 pct Cr x 2000 lb = 780 lb Cr
780 lb x 28.25¢ (market) = $220.35 cost Cr (a)
Assumed Barge Allowance = $12.11 per net ton material (b)
(a-b)/780 lb = 26.70¢ per lb Cr
Cost silicon = 14.60¢ per lb Si
26.70¢ x 0.39 = 10.42¢
14.60¢ x 0.43 = 6.28¢
Cost Fe-Cr-Si = 16.70¢ per lb material

Burnt lime required:

The burnt lime required is obtained by multiplying the regular Fe-Cr-Si by 120 pct. This is equivalent to 280 pct of the required silicon used for reduction where a blend of Fe-Cr-Si is used. Consequently, in the reduction mix the CaO/Si O_2 ratio is approximately 1.30.

Method used to calculate percent chrome oxidation

Fe-Cr-Si and oxygen needed:

If the chrome in the initial charge is 2335 lb (Table III), then 2335 lb x 65 pct = 1518 lb Cr to be oxidized.

1518 lb Cr × 0.404/0.43	=	1425 lb Fe-Cr-Si to use
1518 lb Cr × 5.58	=	8470 cu ft O_2 for chrome
112 lb C × 16.16	=	1810 cu ft O_2 for carbon
Total	=	10280 cu ft O_2 required
10,280 cu ft per 240 cu ft per min	=	43 min blow time

It is recognized that Fe and Mn are also oxidized along with the Cr; at a particular blow rate[3], it remains relatively simple to express percent Cr oxidation for a desired carbon level in terms of the required oxygen and Fe-Cr-Si needed. With types 201 and 202 scrap, where the Mn is predominately higher than in 430 or the 300 series, the total Cr + Mn is treated as being all chromium.

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Udy Process

Applied To Copper Slags

There are some 10 million tons of iron in the slag dump at the abandoned Clarkdale smelter in Arizona—and similar amounts in other dumps around the world. If recovery by the Udy technique proves feasible, an important new source of iron will result.

SELECTIVE smelting by the Strategic-Udy process, already demonstrated on a pilot-plant scale for low-grade ferromanganese and lateritic ores (see JOURNAL OF METALS, March 1957, p. 340, and May 1959, p. 311), is soon to be applied to iron-bearing copper slags located at Clarkdale, Ariz. The result will be a small integrated plant, the first in Arizona.

Undertaking the project are two subsidiaries of Webb & Knapp Inc.: Webb & Knapp Strategic Corp., (partially owned by Strategic-Udy Metallurgical and Chemical Processes, Ltd.) which will construct the plant, and Zeckendorf Steel Co. which will operate it. The latter company's name derives from an Arizona pioneer, who was the grandfather of William Zeckendorf, now president of Webb & Knapp. Koppers Co., closely associated with Strategic-Udy, is conducting the engineering program that will lead to construction of the Clarkdale mill. Buildings and facilities of the abandoned smelter will be used as much as possible. The plant is expected to cost about $15 million and take two years to complete. A Koppers official said that the old smelter was in a remarkable state of preservation, due to the arid climate of the area.

Plant to produce 500 tpd

The Clarkdale slag contains about 33 pct Fe, 0.5 pct Cu, and 2 pct Zn. The process is capable of extracting all of these values, and the remainder, called *slag-slag*, will be processed into building materials. Initial steel capacity of the plant is scheduled to be 500 tpd, which can be expanded to 1000 tpd as demand increases. At this rate, the slag pile will last 30 to 60 years. The building materials plant will have a capacity of 1000 tpd. The integrated facility will concentrate on reinforcing rods and other merchant products. A Webb & Knapp official said that more than one-third of the output of the plant has already been contracted.

Udy process modified

The Strategic-Udy process, developed by the late Marvin J. Udy, is a direct reduction process which employs the principle of selective smelting. As adopted for slag treatment, the process uses an oil or gas-fired furnace to melt the slag, in combination with coal, lime, and reducing agents. Bath temperature is about 2600°F, which volatilizes most of the zinc present, and copper is matted out leaving a copper-free iron-bearing slag. This slag is treated in a Udy-type electric furnace, which gives a semi-refined steel. A third furnace, also electric, finishes the steel to standard specifications. The ferro-copper matte is treated separately to recover the copper values. The residue is processed in the building materials plant into rock wool insulation and concrete building products.

Cost of power unsettled

While power costs in Arizona tend to be high, substitution of the oil- or gas-fired furnace for the tunnel kiln in the melting stage of the process should result in substantial power savings over that previously reported for the Udy process.

The cheapest electric power being supplied to industrial concerns by Arizona Public Service is 8¼ mils at present. While the project will go ahead at this rate, Mr. Zeckendorf feels that an agreement will be reached at 5¾ mils or lower. He cites the inevitable industrial expansion which accompanies steel producing facilities, in addition to the fact that Clarkdale, a ghost town since closing of the smelter six years ago, will be born anew. An unknown factor in the power question is that extensive oil and natural gas drilling is presently going on in the Clarkdale region, with prospects termed hopeful.

Other projects planned

While the Clarkdale unit is the first project, Webb & Knapp also announced that it has contracted with The Anaconda Co. to purchase slag from that company's Anaconda, Mont., property. A plant at this site is scheduled for completion in 1963. In addition to the 40 million ton pile there, the contract includes provisions for the purchase of hot slag, which should result in a further power saving. Other deals are pending with Phelps Dodge Corp. and Kennecott Copper Corp., both of which own large slag dumps.

Webb & Knapp, widely known for spectacular real estate deals rather than metal production, feels that the major economic significance of the process lies in the possibility of building relatively small integrated steel plants in any part of the world where high-grade ores are not available, and where a country or region is dependent on imports for its steel requirements. *J. J. Burke*

KRUPP-RENN EXPANSION

Construction of two mammoth Renn plants in Germany marks revival of interest in this process for the treatment of siliceous iron ores.

by F. Weston Starratt

IMPRESSIVE . . . mammoth . . . these are the words that fittingly describe the new Krupp-Renn plant which is now going into operation at Essen-Borbeck in Germany. Six 360-ft long kilns and a large magnetic separation plant are being put to work providing some 420,000 metric tons per year of high-grade blast-furnace feed for the hungry mills of the Ruhr.

This is the second Krupp-Renn plant to stand on this site. In 1934 Krupp erected a 165-ft kiln in which a large number of test runs were made on a variety of ores and fuels using different types of refractory lining. At the end of 1943 the plant suffered heavy bomb damage; it was dismantled in 1945 and shipped to the Soviet Union.

Other Renn kilns for treating ferrous ore were erected at Salzgitter-Watenstedt in central Germany (1941), Czechoslovakia, Japan, Korea, and Manchuria. By 1945, 38 kilns with an aggregate capacity of 1 million tons were in operation. Many of these were subsequently dismantled by the Allied Powers, and it was 1950 before Krupp was again in a position to design and construct Renn installations.

Recent Krupp-Renn units include a single-kiln plant at Aviles, Spain, which is soon to have a second kiln added. This operation is designed to provide a feed for open-hearth and electric-arc furnaces from ores containing 33 to 45 pct Fe and 21 to 40 pct SiO_2. Spanish anthracite containing about 20 pct ash is used as a reducing agent, and, because of the highly siliceous nature of the ore, the kiln charge includes 17 pct limestone.

A Renn kiln has also been installed in Greece to treat local nickeliferous oxide ores.

Salzgitter and Essen

Construction of a new and larger Krupp-Renn installation on the site of the dismantled Salzgitter-Watenstedt plant was begun several years ago with the financial assistance of eight major Ruhr steel producers. Designed to provide burden for blast furnaces producing basic-bessemer (thomas) pig iron, the Salzgitter kilns operate on low-iron, high-silica, phosphorus-bearing middlings, 2 to 2.5 mm in size, produced by local ore-dressing plants. These middlings average from 31 to 35 pct Fe, 19 to 26 pct SiO_2, 7 to 8 pct Al_2O_3, 4 to 6 pct CaO, and 2 to 3 pct MgO. Coke breeze is used as a reducing agent. The nodular product, called *luppen*, contains up to 1.0 pct P and 0.65 pct S.

The three kilns of this plant were started up in 1956 and 1957, and the installation of a fourth kiln is planned. The present plant has a capacity of 170,000 metric tons of luppen per year.

In August 1959, the first kiln of the six-kiln Krupp-Renn plant at Essen-Borbeck was put into operation while construction work proceeded on the other kilns. When in full operation, this plant will have a capacity of 420,000 metric tons of luppen to feed the furnaces of another group of Ruhr iron and steel plants.

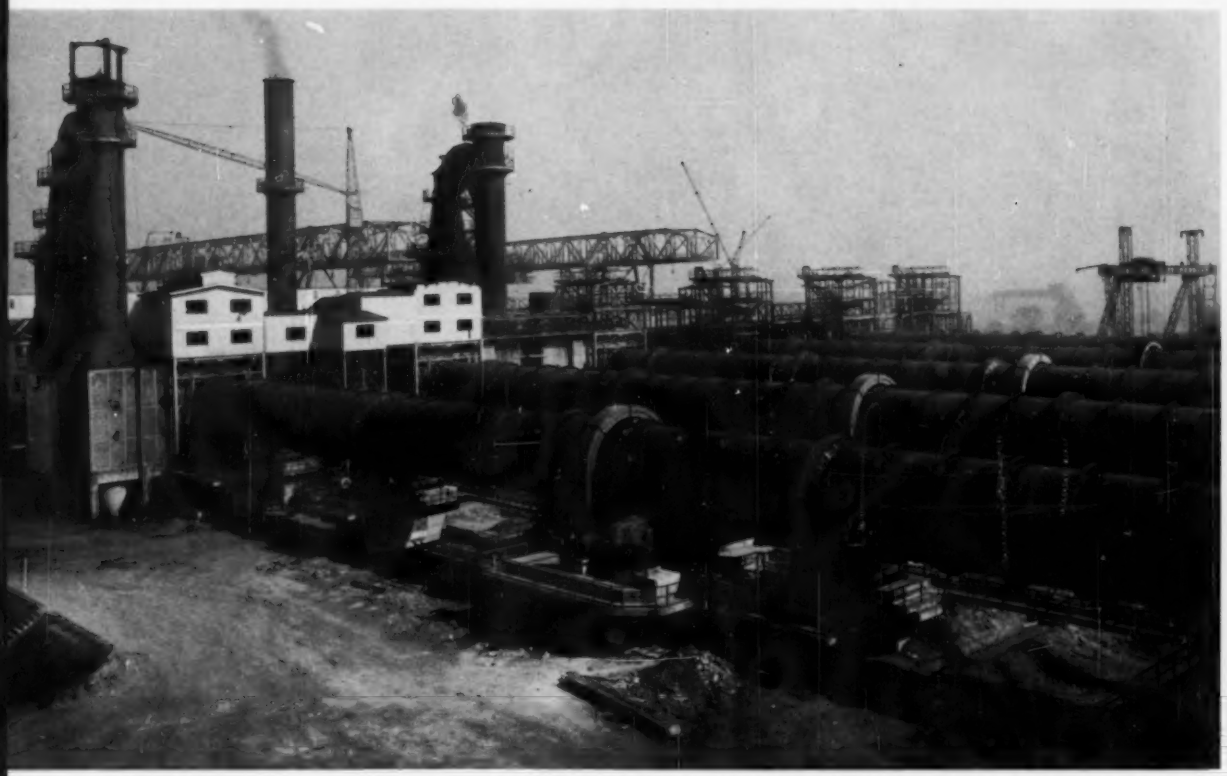
The Essen plant is designed to treat imported low-grade, highly-siliceous iron ores, which are purchased on the world market. These ores, discharged from ocean-going ships at Rotterdam, are to be brought to the plant's own docks by Rhine-river barges and converted into nodules in the 360-ft long, 15-ft diam kilns. Three of these kilns are scheduled to operate on high-phosphorous ores for the production of a blast-furnace feed for basic-bessemer iron, and the other three kilns are to operate on low-phosphorous ores for the production of a blast-furnace feed for open-hearth hot metal and possibly a direct feed for steelmaking furnaces.

This new plant, equipped with large ore bridges and stockage facilities, includes a hammer-type mill for crushing ore to −5 mm size. Normally, however, ores are delivered to the plant in this size and, therefore, do not need to be crushed. Fluxing materials will not generally be required, but facilities have been provided for handling limestone when highly siliceous ores are to be treated. Reducing coke is crushed to −3 mm and screened.

The Renn kilns

The kilns are fired at the discharge end either with oil or pulverized low-volatile coal or coke. A dust removal system, consisting of a large open chamber followed by a Lurgi electrostatic dust precipitator, is located at the charging end of each kiln.

Prior to charging, ore and reducing coke is mixed with flue dust and middlings returned from the magnetic separators. The mixture is continuously charged into a kiln and travels through it in a direction opposite the gas flow. After passing through the preheating zone of the kiln, the iron oxides pass into another zone of the kiln where they are reduced at temperatures ranging from 600° to 1100°C. This is followed by the so-called luppen or nodulizing zone in which the reduced iron welds together to form luppen. These luppen remain dispersed in a pasty, highly-acid, slag at temperatures up to 1250°C.



The luppen zone terminates in a fire-brick ring, which causes the material to build up, thereby being retained for several hours. Since reduction is practically complete, only a small amount of carbon monoxide is released so that the oxidizing heating gases introduced from the discharge end of the kiln impinge directly upon the surface of the charge. This causes a vigorous re-oxidation of the metallic iron exposed at the surface and results in an increase in temperature and the local formation of a fluid ferrous-oxide-bearing slag. This slag segregates from the sponge iron, the metallic skeleton of which welds together to form solid luppen. The oxidized surface layer is worked back into the middle of the charge and is again reduced by carbon particles. As long as the charge remains in the luppen zone, there is a continuous re-oxidation and re-reduction. For an optimum rate of slag segregation and luppen formation, a $CaO:SiO_2$ ratio of 0.15 to 0.3 is maintained. The $Al_2O_3:SiO_2$ ratio should not exceed 0.5.

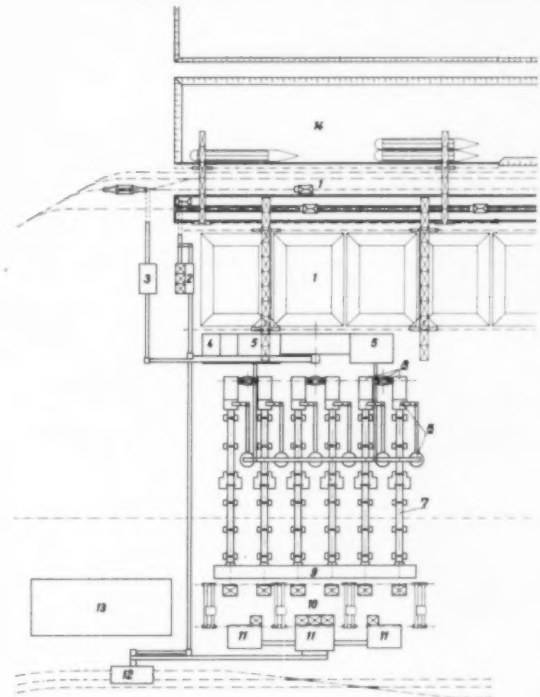
The slow-flowing slag and luppen or nodules are discharged through a cooling kiln into a storage area.

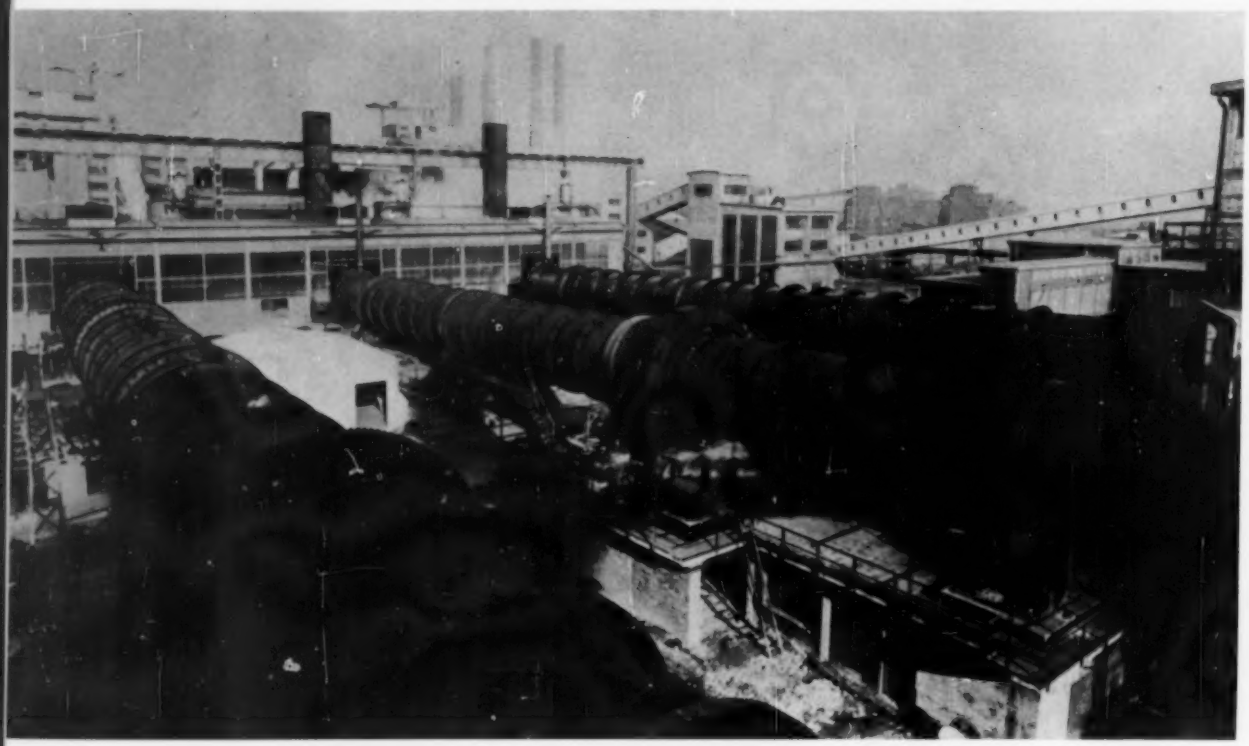
Magnetic separation

From the storage area, the kiln discharge is removed for grinding in slotted tube mills which operate in closed circuit with a vibrating 1-mm screen. This operation serves to free the metallic nodules from the slag.

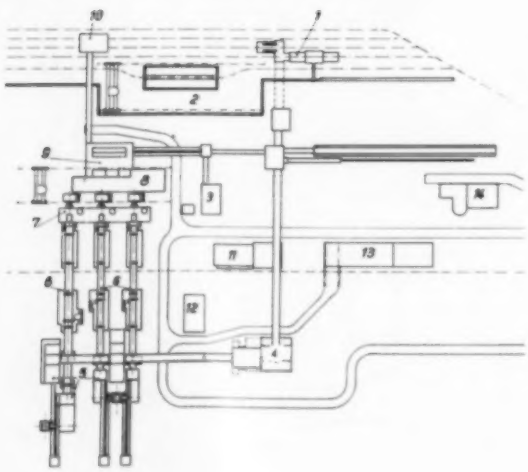
Belt conveyors deliver the ground material to the separating plant where it is first screened into several size grades. The +8 mm is pure luppen and goes directly to storage bins. The smaller sizes are passed over magnetic drum separators where they

Above, Krupp-Renn plant under construction at Essen-Borbeck in Germany. Below, plant layout: 1, stockyard; 2, ore crushing plant; 3, coke crushers; 4, coal pulverizing plant; 5, storage bins; 6, feed hoppers and conveyors; 7, Renn kilns; 8, flue dust chambers and stacks; 9, kiln discharge building; 10, stockyard for discharge; 11, crushing plant; 12, magnetic separators; 13, plant office, etc.; 14, port and ore bridges.





Above, Krupp-Renn plant at Salzgitter-Watenstedt in Germany. Below, plant layout: 1, wagon tipper; 2, stockyard; 3, coal pulverizing plant; 4, coke crushers; 5, kiln charging station; 6, Renn kilns; 7, kiln discharge building; 8, discharge storage; 9, crushing plant; 10, magnetic separators; 11, transformer station; 12, office; 13, workshops; 14, locker rooms.



are divided into luppen, slag, and a magnetic concentrate which is returned to the kiln charging area. This return material constitutes a circulating load of 5 to 7 pct of the ore processed. The slag is processed into building brick for use in construction work. The luppen, which ranges in size from 1.5 to 4 mm, is practically free from slag and contains from 94 to 95 pct Fe.

Desulfurization, a problem

The Krupp-Renn process is particularly well adapted for the treatment of highly siliceous iron (and also nickel) ores. But a distinct disadvantage of this process, as well as other acid processes, is its inability to remove sulfur or phosphorus.

The Krupp-Renn process has been termed an ore beneficiation process by many, although this is not really correct since the ore is actually transformed from an oxide to a metallic form. On the other hand, the process can not be described as a direct-reduction process, since the Renn nodules or luppen can be charged directly into open-hearth or electric-arc furnaces only when the ore itself is low in sulfur and phosphorus. Thus, in actual practice the Renn nodules are generally used for blast-furnace charging.

Krupp-Renn economics

The Krupp-Renn process has several economic advantages. In the first place, large-sized metallurgical coke is not required; instead, almost all fine-grained, low-volatile solid fuels can be used, even those of high ash content. Secondly, the process itself has a high rate of iron recovery . . . about 95 pct . . . and its fuel requirements . . . about 330 kg of coke per metric ton of ore . . . are relatively low particularly when compared with the treatment of high-silica ores in the blast furnace. In addition, the

product, luppen, is already in metallic form and, thus, requires no reduction; it is relatively pure and practically slag free.

Against these advantages must be balanced the operating and capital costs of the Renn operation. As an example of such costs, Table I shows figures for the Salzgitter plant as of January 1958. Capital requirements for the construction of a Krupp-Renn plant should not be minimized. The new Essen-Borbeck plant has been built at a cost of $22 million or $52 per metric ton of annual luppen capacity. Such capital expenditures tend to be prohibitive at a much lower level when the product is used as a blast furnace feed rather than for melting stock in steelmaking furnaces. Processing costs for the German plants are estimated to be $7 per ton of luppen produced.

On the other hand, this is a high-grade charging material for the blast furnace, and the utilization of Renn luppen shows a considerable reduction in coke requirements. Tests have shown that up to 7 pct luppen may be added to the blast-furnace charge without additional coke being required for melting the nodules. In quantities greater than this, additional coke is required. German blast-furnace practice shows that, while some 800 kg of coke is required to smelt 1 metric ton of iron from ore, only 200 kg of coke is required to melt 1 metric ton of luppen in the blast furnace.

In addition, the charging of luppen does, of course, provide a means of considerably increasing the output of the blast furnace. Luppen has been charged in amounts up to 25 pct of the burden, and this factor can be used to provide flexibility of blast furnace production where desired.

Another interesting economic aspect of the Renn process is its utilization to relieve the blast furnace from the necessity of smelting highly siliceous ores. This results in a reduction of flux required for the burden, and a lower blast-furnace slag volume and coke consumption.

The construction of a second mammoth Krupp-Renn plant in recent years is indicative of the faith which Ruhr steelmakers have in the overall economics of the operation. The Salzgitter plant permits utilization of low-grade German siliceous ores by the Ruhr mills, while the new Essen-Borbeck plant permits the purchase of cheaper low-grade siliceous ores on the international market. But, there are those in the German steel industry who ask whether it might not be more economical to purchase more expensive high-grade ores and charge them directly into the blast furnace.

The economics of luppen in the steel industry would certainly be more interesting if it could be charged directly into steelmaking furnaces instead of blast furnaces. Such metallic nodules could be melted either in the electric-arc or in the open hearth furnace. But the sulfur and phosphorus problem has largely prevented their utilization in this manner, although techniques have been developed for removing sulfur from luppen.

When using luppen as a charge for a steelmaking furnace another problem enters the picture. The luppen must be considered, economically at least, as a scrap substitute, and aside from the sulfur problem, the economics of the procedure becomes one of the relative costs of luppen and scrap.

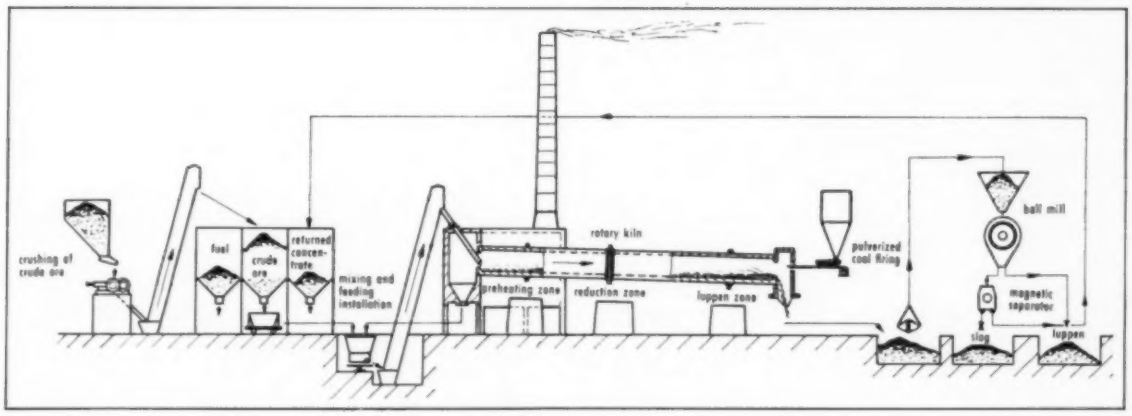
In the overall economic balance, the Krupp-Renn process has found a place in the German steelmaking picture as a means of treating low-grade siliceous ores for the production of a high-grade blast furnace feed. In addition, Krupp-Renn also appears to be a solution to ironmaking problems in areas that have highly siliceous ores and little high-grade coking coal.

Table I. Operating Costs of Salzgitter Krupp-Renn Plant as of Jan. 1, 1958

Operating Data, Metric Tons Per Year		
Consumption of iron ore		616,000
Production of luppen		173,000
Consumption of coke breeze		161,000
Consumption of coal for heating		40,000
Costs	**DM***	**DM***
Ore charge, 3.56 metric ton (about 18.30 DM per metric ton on avg)		65.15
Fuel		
a) coke breeze, 0.935 metric ton (about 64.70 DM per metric ton)	60.50	
b) heating coal, 0.232 metric ton (about 76.50 DM per metric ton)	17.75	
	78.25	78.25
Electric power, 75 kw-hr (about 67.00 DM per 1000 kw-hr)		5.00
Processing costs		'25.00
		173.40
Capital costs		
a) calculable depreciation 8.5 pct of 32.45 million DM	15.90	
b) calculable interests 6 pct of 32.45 million DM capital invested plus 1.0 million DM for stock	11.60	
	27.50	27.50
Operating costs per metric ton of luppen fob		200.90

* DM can be converted to dollars at the current rate of approx. 4.2 to a dollar.

Source: Table I taken from Wiederaufbau und erste Betriebsergebnisse der Krupp-Rennanlage in Salzgitter-Watenstedt, by Dietrich Fastje, in June 1958 issue of *Stahl und Eisen*.



Metal Physics Down Under

. . . An on-the-spot report of the first conference on solid-state physics held in Australia; it was sponsored by the Australian Branch of the Institute of Physics.

by J. J. Gilman

Thirty-two hours of almost constant flying clearly impresses one with the great distance between Melborne, Australia, and the U. S. However, a committee of The Australian Branch of the Institute of Physics, led by Dr. W. Boas, recently made a fine attempt at bridging the 7000 mi by organizing the first conference on solid-state physics to be held in Australia, and inviting several overseas guests to attend. Meeting for one week on the grounds of the University of Melbourne helped break down communications barriers between Australian scientists, as well as helping to establish connections with the outside world.

Through the enlightened policies of the chief Australian research organization, Commonwealth Scientific and Industrial Research Organization (CSIRO) many Australian scientists are able to make a round-the-world trip at about 10-year intervals. This is why they are a rather familiar sight in the large research laboratories of the U.S. However, it was a very unusual event when about 18 overseas visitors descended upon Melbourne to return the compliment. There were nine visitors from the US, five from New Zealand, three from England, and one from Canada. The friendly Australians worked hard to treat the visitors royally and were eminently successful.

Total attendance at the conference was 135, so that well over 100 Australians were in attendance. This testifiies to the success of the meeting, as fundamental research of all kinds in Australia, excluding medical work, is probably done by less than 1000 men.

Technical sessions were held on five mornings and four afternoons, allowing some 46 papers to be presented. The range of topics discussed was very broad, including: theory of superconductivity, alloy theory, thermal conductivity at low temperatures, field emission of electrons, sputtering, theory and observations of dislocations, stored energy release from metals, fracture, the photographic process, studies of optical centers in crystals, paramagnetic resonance, dielectric absorption and breakdown, magnetic studies, and so on. Considered here are just a few things relating to metals that caught my interest.

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Thermal conductivity

At low temperatures, dislocations in crystals scatter thermal waves and thereby reduce thermal conductivity. A theory of this scattering process was published a few years ago by P. G. Klemens of Sydney, Australia. Experiments that use thermal conductivity data to measure the dislocation densities in alloy metal crystals were described at the conference by R. G. Kemp and P. G. Klemens, as well as by H. M. Rosenberg and J. N. Lomer of Oxford University. Alloys of silver and copper were used, and the measurements made as a function of cold deformation and annealing treatments. Although the relative changes of thermal conductivity seem quite consistent with expected dislocation density changes, the magnitudes of the changes are far greater than would be expected from the theory. In other words, theory predicts higher dislocation densities than one expects, and that meager evidence shows to be present. Thus, it would seem that theory predicts insufficient scattering of photons from dislocations. Good simultaneous measurements of thermal conductivities and dislocation densities are needed to clarify the situation.

Metal films

G. J. Ogilvie of Melbourne has performed interesting experiments in which metal surfaces are bombarded with argon ions. For example, if the {111} face of a silver crystal is bombarded, and electrons diffracted from it, slightly disoriented crystallites appear in the surface, and some evidence of stacking faults appears. If a layer of copper is first placed on the surface, some of the copper atoms are driven into the surface by the bombarding gas ions. Also, by sending the incident gas-ion beam through a hole in a clear glass plate, sputtered silver atoms can be collected. They form patterns on the glass plate which indicate that they

preferentially leave the surface along close-packed directions. Finally, if Cu_3Au specimens are bombarded, it is found that the surface layer becomes depleted in Cu. These experiments have considerable implications for radiation damage studies, and reveal some of the effects of surface cleansing and etching by means of cathodic sputtering.

A. K. Head discussed elastic equilibria of arrays of dislocations near the surface of a crystal when a metal film lies on the surface that has a different elastic modulus than the substrate crystal. A high-speed computer has been used to work out a large variety of special cases, and the results indicate that quite thin but stiff films can effectively block dislocations from emerging at a surface.

Deformation

B. E. Warren showed how information about cold-worked metals can be obtained from X-ray diffraction data. He presented a new and considerably simplified method for obtaining the probability of twin-faulting from asymmetries of powder pattern reflections. He also showed how small angle scattering data can be analysed to find the distribution of sub-grain misorientation angles in cold-worked metals. For copper sheet that has been beaten with a hammer, his method indicates that most of the sub-grains make angles of less than 2 to 3° with respect to one another.

Z. S. Basinski of Ottawa, Canada, has found that when aluminum crystals are deformed at 4.2°K, the temperature near an active glide band rises as much as 50°K for $\sim 100\,\mu$ sec. This adiabatic heating effect results in a serrated stress-strain curve. J. B. Lean of Newcastle, Australia, also discussed adiabatic heating during plastic flow in the case of steel. He concludes that adiabatic heating effects are important in the yielding of iron at temperatures at least as high as liquid-air temperature.

Basinski has also studied the deformation of magnesium crystals at very low temperatures. Unlike past authors, he concludes that the mechanism of strain-hardening in hexagonal metals is similar to that in FCC metals, provided recovery is eliminated by keeping the temperature low.

Electrical properties

One of the weaknesses of the band theory of solids is the fact that metals, semiconductors, and insulators remain of the same general type after they have melted; this throws doubt on the role of structural periodicity in determining their electrical behavior. R. E. B. Makinson and A. P. Roberts discussed calculations of the effect of aperiodicities in the lattice potential on the energy-band gap of a one-dimensional crystal. The disordered potential that they used contained both long- and short-range disorder. They conclude that short-range disordering is more effective than long-range disordering in destroying an energy gap in the one-dimensional model.

T. H. Blewitt of the Oak Ridge National Laboratories described the results of recent studies of neutron radiation damage of copper. Recent electrical resistivity measurements have been made on specimens that were bombarded at 3.8°K in a helium liquifier that was built into a nuclear reactor. It was found that the defects produced by radiation damage become mobile and anneal out at temperatures below 7.2°K.

Good evidence of a superlattice in alpha-brass has been found by L. M. Clarebrough, M. E. Hargreaves, and M. H. Loretto of Melbourne. Using their high-sensitivity calorimeter they measure the ordering energy to be only about 0.1 kcal per mol and the ordering temperature to be about 250°C. They also studied the effects of quenching and cold-deformation on alpha-brass, and conclude that unusually high concentrations of vacancies are present as clusters after these treatments.

It may be seen from the above account that various aspects of the mechanical behavior of solids constituted the largest group of papers at the conference. About 18 of the 46 papers dealt with some aspect of mechanical behavior. This is partly a result of current interest in the behavior of dislocations in crystals, but it also reflects Dr. Boas' strong influence on Australian metallurgy and physics. Many of the best young metallurgists there either work in his laboratory or were his students when he taught at the University of Melbourne.

Australian research conditions

Universities in Australia are primarily concerned with teaching; so, most of the fundamental research that is done is dependent upon industry and government. Except for a very small effort in the steel industry, the bulk of research falls upon the various branches of CSIRO. The total annual budget of CSIRO is about £5,500,000 (about $12.5 million). This is $1 to 2 per-capita—on the same order as the amount spent by the various agencies of the US government that do comparable types of research. However, there is far less government support of university research, and less industrial research; so, even on a per-capita basis it would seem that the research budget of Australia is relatively small. This is at least partly compensated by the relatively high quality and low cost of Australian research. . . It costs only about $10,000 per annum to support an Australian research worker as compared to $30,000 to 50,000 in the US.

Isolation clearly has a strong influence on the atmosphere in which Australian scientists work. This manifests itself in several ways, for example, in the extra time that it takes for them to learn new techniques and hear about new phenomena. In addition, it makes it difficult for them to evaluate the quality of their own and overseas scientific work. Also, the range of scientific equipment and talents is limited. Finally, morale is a problem because the *fun* of scientific discussions and gossiping is limited.

These factors are alleviated to some extent by various techniques. One is good air transportation which is currently being markedly improved through jet airliners. Another is the fairly regular world trips already mentioned. Perhaps most important, from the standpoint of everyday work, is the attempt in laboratories to form groups of people working on a single or on allied topics. If such concentrated groups are wisely administered, it is felt that they improve morale by providing the opportunity to talk with others. Perhaps more important is the fact that the best people in a group set a standard of performance which an isolated man would not have. Finally, fellowships are offered to young overseas scientists that include round-trip fares for families. An example of these are the Fellowships in metal physics offered by the Division of Tribophysics of CSIRO. This provides stimulation to Australian science by importing fresh viewpoints from the outside.

DIRECT LEACHING ZINC-SULFIDE CONCENTRATES

By Sherritt Gordon

Oxidation in an autoclave with sulfuric acid has been shown to extract 95 to 99 pct of the zinc present, produce a quantitative amount of elemental sulfur, and avoid loss of zinc due to ferrite formation.

by F. A. Forward and H. Veltman

RECOVERY of zinc by roasting and leaching methods combined with electrolysis has been described fully in the literature since its commercial introduction in 1916.[1-4] Particularly in locations where low-cost electrical energy is available, the process has been used to treat a variety of zinc sulfide concentrates in which zinc is the principal consituent but which also contain appreciable amounts of lead, copper, or iron sulfides.

Among the factors affecting the economic recovery are: a) high iron:zinc ratio in the concentrate which causes excessive formation of insoluble zinc ferrite during roasting with consequent low zinc recoveries; b) efficient recovery of zinc which necessitates using a more or less complex two-stage counter-current leach; and c) the sulfur dioxide produced in roasting which must be disposed of in some manner, and is usually converted to sulfuric acid.

It is reasonable to expect that an advantage would be gained if a process employing the following characteristics was developed: very high extraction of zinc regardless of the iron or zinc content of the concentrate; use of a single stage leach in which no sulfur dioxide is produced, the sulfur content of the zinc sulfide being recovered instead as elemental sulfur. Such a process is delineated below.

Previous experimental work

Space limitations preclude a detailed survey of the literature of this subject, but the interested reader will find sufficient information in the references.[5-19] It should be pointed out, however, that current work[11] shows that galena is oxidized by oxygen under pressure in a sulfuric acid solution at elevated temperatures as follows:

$$PbS + H_2SO_4 + 1/2\ O_2 \rightarrow PbSO_4 + S^\circ + H_2O \quad [1]$$

Björling[12] mentions the reaction

$$ZnS + H_2SO_4 + 1/2\ O_2 \rightarrow ZnSO_4 + S^\circ + H_2O \quad [2]$$

as having been carried out using oxygen under pressure, but points out that it proceeds so slowly that it is impractical for zinc extraction from ZnS unless nitric acid is also present as a promoter. The nitric acid, he states, presents obvious difficulties in subsequent electrolysis. He concludes that because of these difficulties and the added problem of recovering sulfur from the leach residue "acid decomposition of zinc blend is unfavorable."

Unexpectedly, in the face of Björling's results, the present work shows that ZnS can readily be oxidized quantitatively to Zn^{++} and S° in a solution containing H_2SO_4 in sufficient amount to combine stoichiometrically with the zinc in ZnS without nitric acid being present. The necessary conditions for carrying the reaction out efficiently have been developed in a series of laboratory tests, and the principal elements of a cyclic process established.

Zinc sulfide tests

The materials used in the series of tests described were commercial products having the following composition:

	Zn-Pb Concentrate	High Fe:Zn Mixture	Pb Concentrate	Pyrrhotite Concentrate
Zn, pct	41.5	21.0	3.5	0.4
Pb, pct	7.8	4.4	65.5	0.4
Cu, pct	tr	n.d.	tr	n.d.
Fe, pct	10.0	32.0	11.2	50.5
S, pct	24.5	26.5	20.7	32.1
Insol, pct	5.1	7.0	n.d.	12.6

To provide maximum reaction rates, the concen-

F. A. FORWARD is head of the Dept. of Mining and Metallurgy, University of British Columbia, Vancouver, B. C.; H. VELTMAN is a research metallurgist, Research and Development div., Sherritt Gordon Mines Ltd. Paper presented at the AIME International Symposium on the Physical Chemistry of Process Metallurgy, Pittsburgh, April 1959.

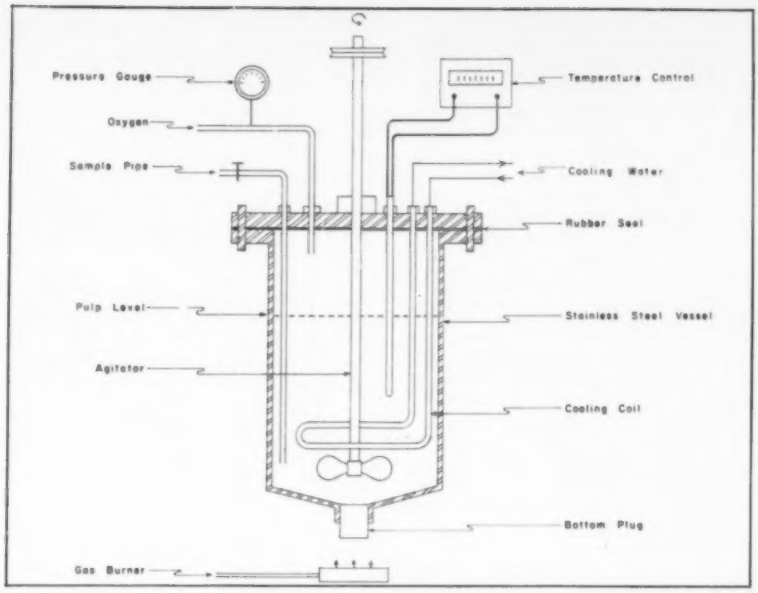

Fig. 1—Diagram of the stainless steel autoclave, 10 x 7½ in., which was used in all experiments.

trates were ground in a laboratory ball mill to substantially 100 pct −325-mesh before leaching.

The leaching tests were carried out in a 10 x 7½ in. stainless steel autoclave, Fig. 1, with external gas flame heating, internal cooling coil and agitator, and equipped with automatic controls which could maintain the temperature of the reacting pulp within a range of ± 3°C. Commercial oxygen was supplied through a suitable pressure reducing and control valve. Samples could be withdrawn at required intervals through a sampling valve.

In conducting a leaching test, the zinc concentrate, usually 500 g, was charged to the open autoclave as a water slurry. The required amount of H_2SO_4 was then added together with more water to give a pulp density of about 14 pct. The autoclave was closed, the agitator started, and oxygen admitted to prevent H_2S formation during the heat up period. Temperature was raised to the required level and residual nitrogen from the air initially present purged by releasing the pressure momentarily. The release valve was closed, the vapor pressure read, and oxygen admitted to give the required partial pressure.

The autoclave was then operated continuously for the desired period—from ½ to 4 hr—the temperature, pressure, and agitation being maintained throughout.

In the tests run above the melting point of sulfur (119°C), the molten sulfur formed globules which *wetted* and occluded unoxidized sulfides and solidified on cooling to form small pellets. In the tests run below the melting point of sulfur, the elemental sulfur formed was finely divided.

Two methods were used for separating the sulfur from the oxidized solids and leach solution: pelletizing and flotation.

Pelletizing: At the end of the leaching period the pulp temperature was raised to 140°C for 15 to 30 min to form molten sulfur globules. Pellets, formed on cooling below 100°C, were separated from the oxidized products and leach solution by screening on a 150-mesh screen. Oxidized solids ($Fe(OH)_3 \cdot xH_2O$, $PbSO_4$, SiO_2, and so on) were separated from the leach solution by filtration and the filter cake washed with water.

Flotation: Pulp at the end of the leaching period was cooled to room temperature, filtered, and the filter cake washed with water. The filter cake was then repulped with water to 15 pct solids and floated with a small amount of xanthate and pine oil in a laboratory cell to produce concentrate, middling, and tailing, the latter comprising the oxidized solids and insolubles.

In some tests, the pellets or flotation concentrates were heated to 400°C to distill sulfur and the residual sulfides returned to a subsequent leach. Separation of sulfur from sulfides by filtering at 130°C was examined qualitatively on both types of product.

A few tests were carried out to examine the removal of Fe^{+++} from leach solutions by pH adjustment with $CaCO_3$. The Fe-free solution was considered to be ready for conventional Cu-Cd removal. No experiments were carried out to test cementation or electrolysis.

Leaching variables

Once it had been established that ZnS reacted quantitatively with H_2SO_4 and O_2 under pressure at 110°C in an aqueous solution to produce $ZnSO_4$ and S^0, tests were carried out to ascertain the conditions necessary for conducting the operation most effectively. Variables examined included: grind, temperature, O_2 partial pressure, H_2SO_4 concentration, time, and zinc ion concentration.

In a subsequent paper[11] the reaction between PbS, H_2SO_4, and O_2 to produce $PbSO_4$ and S^0 is discussed. Although molten elemental sulfur *wets* unreacted sphalerite, chalcopyrite, and pyrite, the coherent layer of $PbSO_4$ which forms on the surface of galena effectively prevents *wetting* by the molten sulfur. Pellets of sulfur, when formed, occlude only inconsequential amounts of lead as PbS or $PbSO_4$. Similarly, in flotation, only the clean sulfides and sulfur will float while the $PbSO_4$-coated galena particles remain with the oxidized products in the flotation tailing.

Grind: The zinc-lead flotation concentrate used in most of the experiments described was dry as received but contained numerous lumps of up to

Table. I Effect of Leaching Variables on Process Operation*

	Effect of Temperature				Effect of Pressure			Effect of H_2SO_4			Effect of Time			
	90°C	110°C	115°C	130°C	140°C	10 Psi	20 Psi	60 Psi	45 Pct	75 Pct	90 Pct	100 Pct	½ Hr	1 Hr	1½ Hr	2 Hr	3 Hr	4 Hr
Solution																		
Zn, gpl	47.0	64.0	75.0	53.0	57.0	48.0	64.0	67.0	38.0	50.0	65.0	72.0	41.0	62.0	64.0	65.0	70.0	72.0
Fe, gpl	7.8	2.3	2.0	0.9	0.9	4.0	2.3	1.0	0.5	0.4	1.0	1.0	5.6	3.0	2.3	0.4	0.6	1.0
pH	0.5	1.1	1.1	0.8	0.8	1.0	1.1	1.0	2.1	1.7	1.4	1.2	0.6	0.9	1.1	1.3	1.3	1.2
Pellets																		
Zn, pct	33.0	15.2	12.5	27.7	25.0	29.0	15.2	5.5	40.0	27.2	11.5	3.8	35.0	17.5	15.2	10.0	6.3	3.8
S°, pct	38.4	69.2	75.4	49.2	52.1	46.1	69.2	86.0	13.9	24.0	73.2	90.4	33.0	55.0	69.2	77.4	85.8	90.4
Residue																		
Zn, pct	1.2	1.0	2.0	2.0	1.7	1.0	1.0	0.9	1.0	0.7	1.0	1.0	0.8	1.2	0.7	0.5	1.0	1.0
Pb, pct	24.7	23.0	18.9	13.6	10.3	18.0	23.0	21.4	23.7	22.8	20.3	16.9	17.3	21.1	23.0	19.9	20.3	16.9
Fe, pct	22.3	27.5	26.1	27.0	30.3	27.0	27.5	32.9	33.8	32.3	31.8	28.7	25.6	34.2	33.7	33.0	32.7	28.7
S, pct	12.0	10.7	11.7	11.5	10.0	10.2	10.7	10.0	5.5	5.6	12.5	22.8†	11.3	7.4	7.0	7.4	10.7	22.8†
Zn Distribution (pct) (based on concentrate)																		
Solution	62	88	90	70	73	70	88	96	51	75	91	97	62	86	88	92	96	97
Pellets	37	11	8	28	25	29	11	3	48	24	8	2	37	13	11	7	3	2
Residue	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1

* Standard Conditions:
Charge = zinc-lead concentrate.
Grind = 100 pct −325 mesh.
Pulp density = 14 pct.
H_2SO_4 addition = 1 stoichiometric amount for Zn + Pb (see Eq. 1 and 2).
Pressure = 20 psi O_2 overpressure.
Time = 1½ hr (4 hr for H_2SO_4 ratio test).
Temperature = 110°C.

† Contains some S° due to pellets passing through screen.

¼ in. diam. The concentrate was prepared in four different ways as follows:

1) 2-hr grind in laboratory pebble mill (100 pct −325 mesh),
2) 10-min grind in laboratory pebble mill (98 pct −325 mesh),
3) Lumps broken by hand in mortar (92 pct −325 mesh), and
4) As received, including small lumps.

The four products were oxidized under standard conditions in the autoclave. It was found that, for this particular concentrate, a light grind like (2) above is required, but no advantage is gained by excessive grinding.

Temperature: In preliminary tests carried out at 140°C it was found that the conversion to $ZnSO_4$ and S°, though very rapid initially, ceased completely in about 10 min giving 65 to 72 pct dissolution of zinc, the higher figure resulting when O_2 partial pressure was increased from 20 psi to 60 psi. In every case, the oxidized residue contained less than 2 pct of the original zinc; the balance of the ZnS remaining undissolved was occluded in the pellets. Continuation of the leach for up to 6 hr at 140°C effected only minor (1 to 2 pct) additional dissolution of zinc.

From this it soon became apparent that, if maximum dissolution of Zn was to be achieved, the reaction would have to be carried out below the melting point of sulfur.

The results of a series of tests in which all conditions except temperature remained constant are shown in Table I. The advantage of conducting the oxidation in the 110° to 115°C range is clearly evident.

Oxygen pressure: In the series of tests carried out to evaluate the effect of oxygen pressure at 110°C (the results of which are shown in Table I) it is apparent that, under the conditions used, increasing the O_2 partial pressure from 10 to 60 psi has a marked effect on the products obtained in 1½ hr. However, reference to the Table also shows that in 4 hr at 20 psi O_2 the results are almost identical to those obtained in 1½ hr at 60 psi O_2. Higher O_2 pressure accelerates ZnS oxidation and conversion of Fe^{++} to Fe^{+++}—a not unexpected result. The final pH is the same in all three examples because in none of the three was all the added H_2SO_4 consumed.

Sulfuric acid requirement: One object of the investigation was to confirm that the extent of dissolution of ZnS was directly proportional to the amount of free H_2SO_4 added. Because the PbS reacts more rapidly than ZnS it was necessary to add H_2SO_4 equivalent to the PbS present and then enough additional H_2SO_4 to give the desired ratio for the ZnS. Tests were run for 4 hr to ensure that the oxidation and dissolution of ZnS had reached a maximum (note effect of time in Table I).

The data provided in Table I show a reasonably parallel relationship between the per cent stoichiometric amount of H_2SO_4 added and the per cent zinc dissolved.

Time: Although it might have been possible to obtain some of the data in Table I by making a single run under the stated conditions and withdrawing samples at suitable intervals, it seemed preferable to run separate tests for the times shown and to establish a material balance for each test.

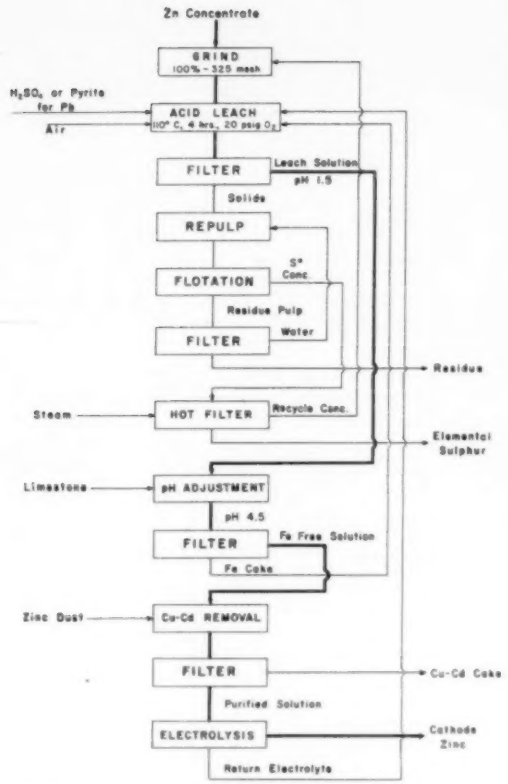

Fig. 2—Flow sheet used to determine effect of zinc ion concentration.

The interesting aspect of this series is that, after 2 hr leaching, zinc dissolution is over 90 pct, the iron in solution is reduced to less than 1.0 gpl, and the pH has reached a maximum of 1.3. It should be noted that the oxidized residue at no time contains more than 1 pct of the zinc.

Zinc ion concentration: A test was made to determine the effect of zinc ion concentration and to approximate the conditions that might exist in a practical operation.

The procedure, which followed the flow diagram shown in Fig. 2, was as follows: A charge of zinc concentrate was oxidized under standard conditions for 4 hr, the sulfur pellets were removed by screening, and the residue filtered off. To the zinc sulfate solution, $CaCO_3$ was added to raise the pH to 4.5 and precipitate Fe^{+++} which was separated by filtration. Concentrated H_2SO_4 was added to the Fe-free solution to give a solution containing 55 gpl Zn and 110 gpl H_2SO_4, resembling return electrolyte.

A second charge of zinc concentrate was oxidized under conditions similar to the first, but using the above recycle solution instead of water. The second product was screened and filtered to give a $ZnSO_4$ solution containing 120 gpl Zn and 1.8 gpl Fe, having a pH of 1.3, which would be ready for purification and electrolysis.

It was found that within the range examined, zinc ion concentration has no adverse effect on leaching.

Sulfur Conversion: It was found that the amount of S° produced parallels the decomposition of ZnS as measured by zinc extraction, thus substantiating, within experimental limits, the stoichiometry of Eq. [2].

Lead concentrate: A single test was run using a 100-pct −325 mesh lead concentrate having the composition: 65.5 pct Pb, 3.5 pct Zn, 11.2 pct Fe, and 20.7 pct S. Sufficient H_2SO_4 was added to provide for conversion of PbS to $PbSO_4$ and S°, and ZnS to $ZnSO_4$ and S°.

In 1 hr at 110°C under 20 psi partial pressure of O_2, the zinc extraction was 89 pct. This is substantially the same as the extraction obtained under similar conditions with the zinc-lead concentrate, as shown in Table I.

High Fe:Zn ratio: To test the effect of high iron content in the concentrate, a charge was prepared by mixing equal parts of zinc and pyrrhotite concentrates. Although not exactly comparable to a natural product, the iron:zinc ratio, which is very high, resembles that in a lead-zinc middling product.

Zinc loss in oxidized residue is less than 5 pct, a result that could not be approached by conventional roasting and leaching methods for a material of this composition.

Discussion

Equation [2] appears to proceed readily to the right at 110° to 115°C when the pH of the leaching solution is below 2.0, the extent of reaction being primarily dependent on the amount of H_2SO_4 present in the reaction mixture. The rate, as may be expected, depends on the surface area of the ZnS, the temperature (below the melting point of S°), and oxygen pressure, but does not appear to be not-

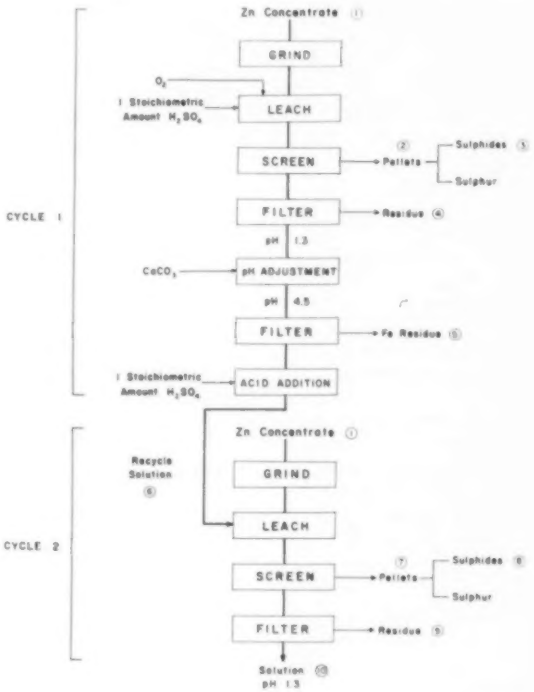

Fig. 3—Suggested flowsheet for treating zinc concentrates. Average analyses would be as follows:

	Zn	Pb	Fe	S_t	S°
Zn conc., Pct	40	8	10	25	—
Leach Solution, gpl	120	nil	1	70	—
Recycle Conc., Pct	23	6	23	29	nil
Purified Solution, gpl	120	nil	nil	62	—

ably affected by the concentration of Zn^{++} and SO_4^{--} ions in the leach solution. Agitation, which also affects the rate, was not studied independently in the present investigation.

As the zinc concentrate used in the majority of the experiments contained marmatite (Zn, Fe)S it is apparent that the substitution of some iron in the ZnS lattice does not adversely affect the progress of the reaction. The galena (PbS) present, amounting to about 10 pct, reacts with H_2SO_4 at 110° to produce $PbSO_4$ and S° according to Eq. [1].

This reaction, as shown in a subsequent paper[11], is much more rapid than the corresponding reaction with ZnS and is substantially complete by the time 5 pct of the ZnS has reacted. Therefore, in most of the experiments described, a stoichiometric amount of H_2SO_4 for the lead present in the zinc concentrate was also added.

In the early stages of leaching a small amount of iron is dissolved as $FeSO_4$ but, as the reaction proceeds and the amount of ZnS present decreases, the Fe^{++} present is oxidized to Fe^{+++} in which form it hydrolyses and precipitates. The rate of oxidation of Fe^{++} to Fe^{+++} was not studied in detail, but it was observed that the final total iron content of the leach solution could be reduced to less than 1.0 gpl.

Since the leach solutions produced were substantially similar to those produced in conventional zinc leaching operations, and since it was considered that they could be purified in the conventional manner (for electrolysis), no purification tests were carried out with the exception of the examples in which $CaCO_3$ was added to increase the pH to about 4 to 4.5 to precipitate most of the dissolved iron. The behavior of arsenic and antimony, present in small amounts, was not examined, nor were copper and cadmium removal attempted. The distribution of silver was not examined, but it is assumed that any dissolved silver would be precipitated in the course of Cu-Cd removal, the remainder reporting in the oxidized residue.

In a number of tests, the pellets and flotation concentrates were heated to 400°C to remove S° by distillation, or were heated to 130°C to separate sulfur from sulfides by filtration, the residual sulfides reground and returned to a subsequent leach. This sulfide product, primarily consisting of the unreacted cores of original ZnS particles or ZnS that had been coated with elemental sulfur, leached as readily as the original concentrate.

The present study does not pretend to provide data relating to the details of the reactions involved or to offer an unequivocal explanation of any of them, or even to define all the limits. One could justifiably postulate that the S° produced in the reaction is derived from the ZnS, but this remains to be proved, possibly by the use of radioactive tracers. The role of Fe^{++} and Fe^{+++} has not been defined.

Conclusions

It has been shown that it is possible to treat a finely ground zinc concentrate with a solution containing about 60 gpl Zn and 10 to 12 pct free H_2SO_4 by agitation in an autoclave at 110°C using an O_2 pressure of 20 psi to extract 99 pct of the Zn from a 40 pct Zn concentrate in 2 to 4 hr. The lead present is converted to $PbSO_4$ and is present together with iron hydroxide and other insoluble oxides in a residue which is separated by filtration.

The sulfur present in ZnS can be quantitatively converted to S° and can either be converted to pellets or separated as a high-sulfur concentrate by flotation, thus obviating the necessity of producing sulfur dioxide or sulfuric acid in an electrolytic zinc operation. Sulfur can be separated from the pellets or concentrate by hot filtration and the undissolved ZnS returned to the leach.

The resulting solution, having a pH of 1.0 to 1.5, and a Zn^{++} content of 120 gpl or higher, should be amenable to purification by conventional methods prior to electrolysis, which would produce cathode zinc and regenerate H_2SO_4 for recycling to a subsequent autoclave leaching operation. The residue containing lead and other materials could be treated by conventional procedures described in a subsequent paper[11].

Although the H_2SO_4 required for reaction with ZnS is regenerated quantitatively by electrolysis, it is obviously necessary to supply the H_2SO_4 from outside sources to react with PbS. This comparatively small amount can be added as manufactured acid produced from sulfur liberated by the leaching reaction.

The flowsheet in Fig. 3 depicts, in outline, a suggested procedure for treating a zinc concentrate. The data show that zinc extraction of more than 95 pct can be obtained in this way regardless of the Zn:Fe ratio in the sulfide mixture, and that zinc extraction is independent of the lead content of the starting material, providing sufficient H_2SO_4 is added to react with PbS present.

Autoclave design and techniques are well established for treating sulfide materials at 100 psig and 110°C using solutions at pH 1 to 2[17]. The amount of heat generated by the reaction should be sufficient to maintain the autoclave at reaction temperature. The amount of air required is only that necessary to oxidize S^{--} to S° and to oxidize the iron present. The design of a plant and the selection of optimum operating techniques and conditions would necessarily require careful study in a suitable pilot plant.

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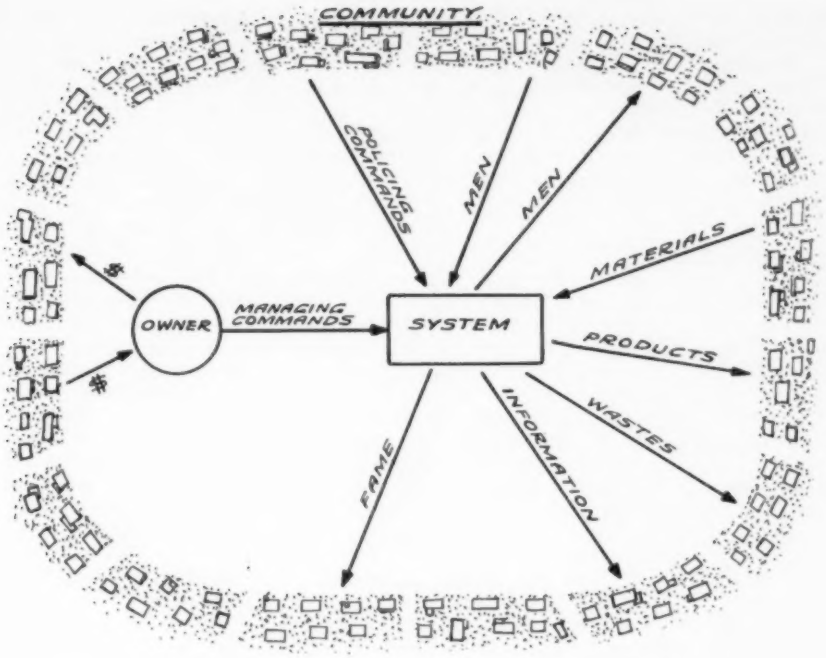


How to Choose THE BEST METALLURGICAL REACTOR...

A System Viewpoint

The choice of a reactor for a metallurgical process is considered from the viewpoint of the system as a whole. The objectives of the system and its exterior design requirements as well as the interior system design are a part of this concept.

by Joseph F. Skelly

THE mineral industry has been pioneering in the development of reactors for chemical processes for many centuries. The fixed bed reactor, the moving bed reactor, the rotary kiln, and even the fluidized bed grew in one aspect or another out of the handling of mineral substances. Despite this fact, the chemical industry sometimes considers itself as the major source of reactor types which are now beginning to attract attention in the metallurgical world. This notion is not correct. But through diligent research and development the chemical companies have brought reactors to a high degree of commercial utility. Thus, it is now possible to contemplate the use of various reactor types in the design of a new metallurgical process installation.

The mineral industry is facing a relatively new problem: the selection of the best possible reactor for any given situation, from the many which are technically practical. We can encounter difficulties in making this choice if we approach the question only from the standpoint of the relative scientific merits of existing reactor types. This frame of reference, which we will call the *component viewpoint* has value at certain stages in the search for a suitable reactor, but it is not a satisfactory general starting point. Experience in the metallurgical, chemical, electronic, ballistic, and communications industries teaches us that it is better to use the *system viewpoint*. This paper deals with the system viewpoint and its use in selecting reactors for treating minerals.

In making a reactor selection, the systems engineer begins by examining the entire mineral handling installation of which the reactor is to be a part. Into this mineral system come men and materials, from the system emerge products, wastes, and men at the end of the day's work. External to the system there is an owner who issues managing commands (to the system) based upon a flow of money between him and the particular economic and social community where the system is located. There are also the policing commands directed to the system by various local pressures, such as the government, the local mores, social customs, and taboos. Waste

JOSEPH F. SKELLY is with the M. W. Kellogg Co., New York. This article is based on a paper given at the Symposium on the Application of the Fluidizing Reactor to the Mineral Industry, conducted by College of Mines, Univ. of Arizona, Tucson, March 1959.

disposal regulations, tax laws, labor union demands, and many other forces make it clear that the choice of components for our system is strongly influenced by relationships between the system and the community. The systems engineer must find a compromise between the forces and pressures which confront him. This compromise must be based solidly upon the objectives which the system is to achieve.

System objectives

While most commercial installations have the familiar objective of making a product to be sold at a profit, some plants are primarily intended to provide technical information. Government agencies sometimes build plants mainly for this purpose.

During wartime, system design choices must often be based on the availability of certain raw materials. And in today's underdeveloped countries, one of the prime objectives of a new plant is to give useful employment to otherwise non-productive people.

Just as there are objectives for the system, so also are there boundary conditions which constrain the systems engineer. While cost is familiar to us all, we may overlook other restrictions, such as start-up time, categories of necessary labor, and the scarcity of materials of construction.

Exterior design requirements

Raw materials: We will now consider some of the characteristics of the sources of raw materials with which the system must deal. Those who supply raw materials (ores and fuels) to the system wish to be able to supply materials of variable composition and physical properties at a constant rate. The miner and the coal dealer would like to ship their raw materials with the changeable characteristics found in natural deposits, and they would also like the system to accept their materials at a steady, predictable, guaranteed rate. On the other hand, the users of the finished products have exactly the opposite desires. They want the chemical and physical properties to be uniform at all times, in spite of the fact that the users consume products at a variable rate. Our system and its reactor must therefore be able to accept raw materials of variable properties while still producing a relatively uniform product.

The conflicting requirements of the raw material suppliers and the product users can be accommodated, to some extent, in the design of a flexible process. For the most part however, these adjustments will have to be made by relying upon surge capacity, i.e. stockpiles and warehouses.

Waste disposal problems, both from the standpoint of public nuisance and the need to prevent the loss of valuable product, often help in the choice of the best reactor for a given mineral processing system. It can be instructive to consider competing reactors as though they were simply devices for the production of waste products rather than marketable products. In this sense, wastes are negative values which detract from the overall profitability of the operation. The ideal system produces, substantially, none of these negative values.

Energy requirements are important in determining the operating cost of any process system. In making this appraisal it is necessary to take into account the fact that energy can be brought into the plant in many forms.

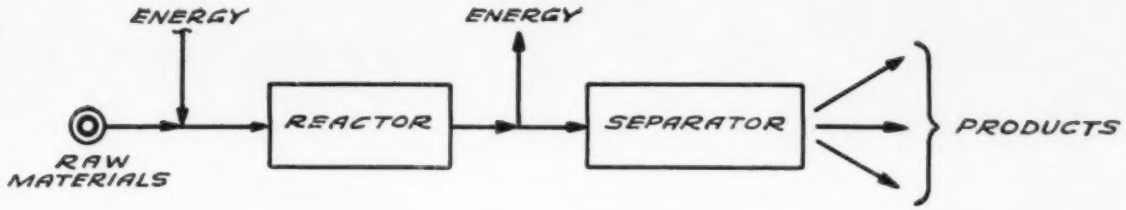
Advertising and other promotional copy often claim phenomenally low energy consumption for new processes and reactors. Sometimes this refers to only one particular kind of energy. Other forms of energy also needed in the process are not mentioned. The iron ore reduction field at the present time is frequently greeted with statements which would make the uninitiated think that the first law of thermodynamics no longer applies.

The foregoing paragraphs constitute a brief discussion of *exterior system design.* It deals with the problem of developing a comprehensive, quantitative picture of the total environment in which the system will have to operate. It describes the forces and pressures which will bear on the system, and it considers their influence on the selection of components. Having developed the exterior system design to some extent, the systems engineer is then ready to consider the *interior system design.* This is the familiar problem of deciding upon the general process to be used in the system and of selecting the individual pieces of equipment which will be assembled in the construction of the new installation. In doing this, the skillful designer is continually guided by his knowledge of the exterior system requirements.

Interior design requirements

In general, any processing system for the handling of chemical or mineral raw material consists of a network of alternating reaction and separation zones. In the reaction zone the material undergoes extensive chemical or physical changes. The effluent from a reaction zone usually consists of a mixture of materials. There will be a relatively large amount of the desired end product mixed with some unchanged raw material. In addition, there will usually be undesirable byproducts formed during the reaction. The mixture then flows to a separation stage where the valuable material is separated from the other substances. The unconverted raw material is usually re-cycled back to the first reactor, while the undesirable wastes are disposed of in some other fashion. From this admittedly abstract viewpoint we would classify grinding as a physical reaction step, while roasting would be a chemical reaction step. For the remainder of this paper we will deal with chemical changes.

The chemical reaction zone usually requires the input of energy to the feed material before it can participate in the desired chemical reaction. Most of this energy will be heat needed to bring the feed up to the desired high temperature and there may also be some mechanical energy for movement or compression. The products leaving a reaction zone are, therefore, hot and must be cooled down in most cases before they can enter the succeeding separation zone. Thus, the reaction zone is preceded by an energy input stage and followed by an energy withdrawal stage. To reduce energy costs, we will favor reaction systems which provide means for exchanging energy between the cooling down of the product and the heating up of the feed. From this point of view it will be apparent that certain reactor types have fundamental advantages. This is despite the fact that any reactor system can be equipped with reasonably satisfactory heat exchange devices. In comparing claims for energy efficiency of various reactor types, it is helpful to inquire into the heat exchange facilities. In many cases, reduced energy



requirements in a new reactor design come about simply because the new unit contains heat exchange facilities which are superior to those available in older types.

Temperature control: The relative importance of temperature control in the reaction zone has a powerful influence upon the choice of reactor type. In general, the fluidized bed provides for much more uniform reaction temperature than do the fixed bed, shaft, and rotary kilns. Because there are some unavoidable disadvantages to the fluidized powders, the systems engineer must determine the relative value of temperature control in his process. Temperature control is usually very important when there are competing reactions which can take place between the various chemical substances present in the system. This is particularly serious in many organic chemical plants. Here the designer wishes to subdue the formation of unwanted byproducts and to prevent catalyst damage by high temperature. In metallurgical processes, this catalyst problem is usually not present, but temperatures above those at which the reactants begin to attack the construction materials used in the reaction chamber itself must be avoided. Some success has been achieved in the maintenance of close temperature control in rotary kiln reactors (for example, the R-N process for the reduction of iron ore), but it is easier to control temperature in the fluidized bed than in the other types of reactors. However, the superiority of the fluidized bed exists only so long as the desired operating temperature is below the fusion point of any of the solids present in the system. It appears to be difficult to maintain fluidization when the solids are at temperatures close to the sticking point.

Chemical potential: In designing the reactor component of any chemical processing system, it is important to consider the effect of reactor type on the chemical potential. This chemical potential is usually greatest when there is counter-current flow of reacting materials. If a reactor produces an intimate mixture of the reacting substances with comparatively uniform composition throughout the reaction zone, the chemical potential is generally at a minimum. Since the size and the cost of the reactor will usually be inversely proportional to the chemical driving force, counter-current reactors are usually cheaper than continuous stirred tank reactors. The fluidized bed is a continuous stirred tank reactor (in the jargon of the chemical kinetics experts) and will be larger for a given chemical job than counter-current reactors operating at the same temperature. This additional reactor cost is often not too significant in evaluating a reactor type because of the fact that reactor cost is often a relatively small part of the total system, but it should nevertheless be evaluated as part of an orderly system design study.

Waste removal problems may influence the choice of reactor type. In general, the more finely divided the solid particles in the system, the more difficult it will be to recover these solids and prevent their eventual discharge into the atmosphere. When we handle dusts which are either very valuable or very obnoxious this question should play a major part in the selection of the best reaction component. Fixed bed and shaft reactors, charged with lump or pelletized feed, will usually offer fewer dust recovery problems than will the fluidized powder reactor which must have finely-divided particles. The rotary kiln, which produces fines through mechanical attrition, usually lies between the fluidized bed and the fixed bed in dust collection difficulties.

Materials handling: An important group of components in the interior design of a metallurgical processing system is concerned with materials handling. Economy and product uniformity are generally improved if the reactor permits continuous operation of the materials handling apparatus. The importance of this consideration increases as the size of the plant increases. Fixed bed reactors are obviously intermittent and, therefore, cannot be directly connected to continuous materials handling machinery. The shaft, rotary kiln, and fluidized bed reactors may allow continuous feed input and product output—a fact which substantially increases their attractiveness. However, the value of this element is greatly diminished if the reactor operates at high pressure. All high-pressure mineral processing reactors must be supplied by intermittent feed conveying equipment because component engineers have, as yet, failed to perfect a continuous pumping device capable of moving large quantities of solids through a big pressure differential.

A difficult choice

While it is comparatively simple to enumerate the various factors that should be taken into account in the design of an optimum system, the reactor choice problem is very difficult in practice. We are often surprised to discover that rather drastic changes in reactor type may have comparatively small effect upon direct investment cost and operating cost for the overall system. In these cases, the systems engineer must base his choice on factors which are not susceptible to numerical evaluation. Operating simplicity, safety, atmospheric polution, maintenance difficulties, and so on, should be considered. As a result, designers at different locations may select different reactor types for the same metallurgical process. The long and variegated history of iron ore reduction aptly illustrates this situation.

Chemical kinetics and systems engineering do not change the basic problems confronting the designer of a metallurgical process. After he carries numerical calculations as far as possible, he must still make major choice decisions. The new sciences simply direct his judgment to higher levels, where there is still no substitute for experience, common sense, and impartiality.

Electric Furnace Refractories

By C. E. Grigsby and W. F. Rappold
of General Refractories Co.

Outstanding developments in quality and application of refractories for basic electric-arc steel furnaces have taken place in the last few years.

Today's trend is toward *balanced* linings, having each section built with refractories that will give maximum length of service. Thus, all parts of bottom, wall, or roof can be replaced at the same time as other parts of that section. The furnace is then pushed for production, and the lining judged on the relationship between number of heats, production, and cost per ton of steel.

Bottoms

Original construction: Operators of basic open-hearth and electric-arc furnaces agree that the bottom which can best resist basic slags is one having the greatest weight of MgO per cu ft. The best bottoms comprise dense burned magnesite brick—92+ pct MgO—covered with dense 92+ pct MgO mix. Since burned magnesite brick have higher thermal conductivity than most other basic refractories, all-magnesite bottoms conduct most heat out of the furnace —giving *coolest* basic bottoms. Thus, maintenance is reduced by elimination of *soft* bottoms and banks which result from refractories of low thermal conductivity.

Thick banks are eliminated in the most modern furnaces by having the pan parallel to the working surface. New bottoms in large furnaces of the most modern electric shops are cool inverted domes—usually two soldier courses of burned 92+ pct MgO brick and rammed 92+ pct MgO working surface. Domed bottoms are impractical in small furnaces; the best bottom under 12-ft diam is made with 92+ pct MgO burned brick and ramming mix in *stadium* construction. In small furnaces with a *dished* shell, many operators still use 9-in. straight fireclay, brick, topped by magnesite brick parallel to the shell in herringbone pattern, with magnesite ramming mix on top of the magnesite brick.

In large furnaces having domed bottoms consisting of 18 in. of 92+ pct MgO burned magnesite brick and 10 to 12 in. of 92+ pct of MgO ramming material, the shell will not overheat if the bottom is properly maintained. The more modern shops get up to 10 pct more furnace capacity and eliminate bottom and bank troubles in cool domed bottoms by using several safety thermocouples in the subhearth, below points of most severe refractory erosion. The hot junction—located 9-in. below the top of the magnesite brick—normally reads from 1000° to 1200°F. When any of these thermocouples reads 1400°F, slightly heavier fettling of double-burned dolomite is concentrated in the hot face area above the high-reading thermocouple. As every steel man knows, no bottom is any better than its maintenance, and burned magnesite brick must be kept well covered to eliminate spalling. For bottoms 18 in. thick or under, 3 in. of fireclay brick next to the shell will keep it below 500°F.

Some operators of large furnaces producing stainless insist on cool domed bottoms having 18½ in. of high MgO ramming material above 13½ in. of 92+ pct MgO burned brick. This cool-bottom idea resulted from excessive maintenance of soft bottoms and banks in well-insulated bottoms tried in open hearths some years ago.

Bottom maintenance

Slag line and banks are usually fettled with double-burned dolomite after every heat. It sinters rapidly into place—only to be eroded or corroded away by metal and slag during the heat. The practice of using 80 to 85 pct MgO ramming mixes of damp-molding-sand consistency to fill holes in bottom and banks is being replaced in many shops, by one of two methods—both of which give a more dense, higher MgO, longer-lasting patch.

In the first method, deep holes are filled with water, then dry 80 to 85 pct magnesia ramming mix is poured into the boiling water until the hole is filled with the ramming mix. Shallow holes are filled by repeatedly pouring into them a batch of very thin soupy 80 to 85 pct MgO ramming mix, letting it boil dry, and repeating until the hole is full. In both methods, the patch is topped with dolomite, giving a dense, hard patch containing almost twice as much MgO as can be obtained with damp ramming mix.

In the second and most recent method, holes in bottoms and banks of both open hearths and electrics are rapidly repaired by filling the holes with specially selected natural magnesite grains. The composition—82 to 84 pct MgO—and grain sizing of this product is such that no additives are needed to make the material sinter rapidly into place. Within the past few months, many open-hearth shops have standardized on this material, and many electric-furnace operators are now doing likewise.

Walls

Basic brick with internal and external steel plates: These brick comprise two or three sections—by means of internal steel plates—thereby utilizing the fundamental principle that thermal spalling of refractories is directly proportional to their size. With silica brick, 60 pct increase in area gives 340 pct increase in time required to heat brick to 1472°F without cracking.

Unburned steel-plated basic wall brick with one or two internal plates give better service than any other brick where spalling due to thermal shock is so severe that steel-plated brick of 4½x3 in. cross section spall excessively. In most furnaces where undercutting is not serious, best results are obtained with properly plated chrome-magnesite brick, because they expand and contract less than magnesite or magnesite-chrome brick. For maximum resistance to undercutting, unburned magnesite brick (88 pct MgO) are best. The brick should have 4½x3 in. cross section with two internal plates

for intermittent service, and 6x3 in. cross section with two internal plates for large, hot furnaces on continuous service.

For ordinary furnaces of all sizes, magnesite-chrome brick with the proper external and/or internal plating for the service conditions, usually give the best balance between resistance to undercutting and spalling.

Two-tone walls: Another way of getting marked improvement in wall life and minimum cost per ton of steel is to use two-tone walls comprising two different types of brick—each suited to service conditions it must meet. In this construction, the lower one-third of steel-plated section, which undercuts due to slag corrosion and metal erosion, is built with unburned magnesite brick (88 pct MgO) having external and/or internal steel plates to suit conditions. The upper two-thirds of the wall is built with chrome-magnesite brick properly plated for maximum resistance to thermal shock—the chief cause of failure in that section. In hot spots of some very hot furnaces, where steel plates melt out 1 in. or more back of the hot face, best service results from brick 6x3 in. cross section having one internal plate and no edge plates.

Fused-cast brick: Another major development has been the rapid acceptance of fused-cast magnesite-chrome brick in hot spots—sometimes with a 6 to 18 in. high zone around slag line as well. Such construction, coupled with two tone walls, has resulted in a 50 to 100 pct increase in service in some very tough furnaces (as compared to walls built with a single compromise brick having fairly good resistance to both slag and spalling).

Wall Maintenance: Even with zoned linings of three kinds of brick, it is impossible to predict exactly zones of greatest wear. Thus, it is usually economical to gun thin sections after every heat near the end of a campaign to get maximum wear from the balance of lining. Gunning materials cover the range from dolomite to magnesite, as well as chrome and chrome-magnesite materials. For most furnaces, magnesite gun mixes last longer and are more economical than lower cost, lower MgO materials.

Gunning is done with either wet or dry guns, and when done properly—with the roof over the furnace to keep the lining hot—the life of walls and roof has been doubled as compared to the same furnace and refractories gunned with the roof off the furnace.

Roofs

In electric furnace roofs, the most important change is rapid replacement of silica brick in large furnaces with super-duty fireclay, 50, 60, 70, 80, 85, or 90 pct alumina, or basic brick or some combination of these. The alumina may be obtained from cyanite, sillimanite, synthetic mullite, diaspore, bauxite, tabular alumina, or some combination of these. Both burned and unburned high alumina brick are being used successfully.

No more cutting: Cutting has been eliminated and service of center section has been doubled in some plants by use of the proper super-duty fireclay plastic or castable, 60 or 70 pct alumina plastic, or 80 or 90 pct alumina ramming mixes—used within the electrode circle wherever full-size brick will not fit. Roof building time has often been cut to one-half or one-third that needed with *cut in* centers.

Silica brick roofs: With silica brick, spalling of the usual large skew brick is often the chief cause of short roof life. With skews one-half as large or less, cost of skew brick per roof is reduced and roof life increased in most furnaces. In many plants, elimination of both silica brick and skews has reduced cost of roofs per ton of steel. In some plants, roof life with standard silica brick has been doubled by using dipped joints of super-duty silica mortar; this reduces spalling by eliminating penetration of heat into joints.

Super duty clay and zoned roofs: Regardless of kind of brick used in the major part of roof, more and more plants are using balanced roofs comprising several types of brick, each giving maximum service at minimum cost for the zone in question. Many plants use complete super-duty clay roofs successfully, while others use super-duty clay brick with 70-pct alumina brick around the electrodes, or in hot spots, or both. In other plants, electrode ring brick are 80 pct alumina with 80-pct alumina ramming mix around them, and 60 pct alumina brick outside the electrode section. The idea is to get all parts of roof wear out at the same time. In most plants, the center section will not last as long as outer rings, but some plants, which have improved center sections, now have trouble near the skews.

High alumina roofs: These are rapidly coming into favor for all sizes of electrics and with all types of steel. The most popular roof of this type comprises spall-resistant 70-pct alumina brick, with 80-pct alumina ramming mix in the center section. These roofs are replacing both silica and super-duty fireclay roofs, but in some plants a close competitor to the 70-pct alumina on cost per ton of steel is a roof with 60-pct alumina brick and 70-pct alumina plastic. A few plants use complete roofs of either Sillimanite (Mullite), 80-pct or 90-pct alumina brick, or ramming mixes—usually in small furnaces with intermittent operation or making special steels. Complete roofs made with various types of castables have generally not been economical.

Basic roofs: Increased use of all-basic roofs in open-hearth furnaces in the US has caused greater interest in basic brick for electric furnace roofs. Basic brick are fundamentally sound because furnace fumes are strongly basic. Several plants have used basic skews, or skews plus outer rings—with or without basic panels in hot spots—for many years, and several plants in Europe have been using basic roofs on small electrics for years. The chief problem in all-basic roofs for electrics is that no steel plates can be used in the center section. Even with continuous operation the best brick for outer sections of very hot, 150-ton furnaces has been found to be 4½x3 in. chrome-magnesite brick with two internal plates. These brick were laid with air-setting chrome-mortar and rings keyed very tightly to avoid sagging when the furnace was tilted.

In many electrics, including these 150 ton furnaces, basic brick are needed only in hot spots, but all-basic roofs with hot patching in hot spots—as in basic open-hearth roofs—may be economical where maximum furnace availability is needed. At present, it appears the center section problem may be solved by 90-pct alumina ramming material around the electrodes, plus center sections thicker than the outer roof.

Several plants in this country are now trying basic roofs on furnaces of various sizes and, since such roofs are fundamentally sound, it is believed that, in due time, basic roofs will be standard practice for most electric furnaces.

Electrode coolers not needed: One of the most rapid changes in roof practice today is replacement of electrode water coolers with home-made, prefabricated, refractory *doughnuts* the same size and shape as the coolers. This is better than chaining coolers to the roof frame to eliminate injuries from explosions resulting from water-filled coolers falling into bath with a collapsing roof center. Refractories duplicate the only essential function of coolers in most plants—they restrict the opening around electrodes, thus preventing flame from damaging roof steelwork. Generally, little or no increase in consumption of electrodes or electrode ring brick is noted. The refractory doughnuts are cheaper, easier, and faster to install, and they eliminate leaks which cause delays and possible injuries during repairs. The doughnuts are built with steel-reinforced high-strength fireclay castables, plastics, or arch brick when service is easy; and with plastic chrome ore, high-strength basic castables, ramming mixes, or unburned basic arch-brick when service is tough.

Another Swindell-Dressler

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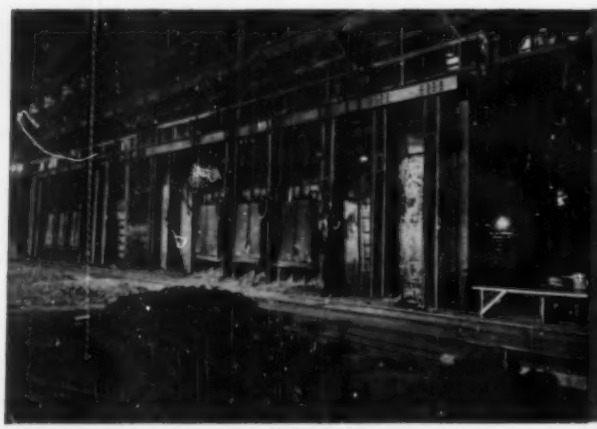

The original open hearth shop

Open hearth demolition—March 17, 1959

This project involved demolishing four large open hearth furnaces, including charging platforms, ramps, trackage and stacks to permit installation of a new, modern electric furnace melt shop facility for Midvale-Heppenstall in Philadelphia. An existing 50 ton Swindell arc melting furnace was modernized for transfer to the new melt shop adjacent to two large new Swindell arc melting furnaces of latest design. These three Swindell furnaces afford a range of heat sizes of 35, 70 and 100 tons, or can produce a combined heat in excess of 200 tons. These furnaces are equipped with modern hoods for fume removal and with provisions for future vacuum practice. An induction stirrer has been provided on the smaller of the two new furnaces and provisions have been made on the foundations of the two larger units for future installation of the rotor type induction stirrers.

The project included transformation of the old gas producer lean-to building into a modern indoor scrap handling and storage area featuring a new concept of scrap handling for segregated storage and charging.

A modernized teeming bay features equipment and vacuum tanks for ladle degassing of heats to 200 tons.

Space does not permit the many additional items of equipment and construction furnished on this major modernization job —accomplished for the customer in a minimum of time.

Turn-Key Melt Shop

The go ahead—May 5, 1958

Job progress—June 19, 1959

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AIME METALLURGICAL SOCIETY OF AIME NEWS

Arizona Fall Meeting At Tucson Dec. 7th

The Fall Meeting of Arizona section, AIME, is being held Dec. 7th at the Pioneer Hotel in Tucson. Each of the Section's technical subdivisions: smelting, mineral dressing, underground mining, open pit mining, and geology is conducting its own part of the program. Details are incomplete at this writing, however, the smelting session will include a paper on Gaseous Reduction of Oxygen-Bearing Copper, by Dr. Leonard Klein, Phelps Dodge Corp. Papers will also be presented on milling problems at Copper Cities div. of Miami Copper Co. and cyclone primary classifiers at Silver Bell.

Portland to Host Pacific Northwest Conference in 1960

Two days of metallurgy sessions are planned for the 1960 Pacific Northwest Regional Conference, to be held at the Sheraton Hotel in Portland, Ore., Apr. 28-30.

Refractories for the Aluminum Industry is the title of one such session. Three major refractories manufacturers have been lined up to present papers at that time. Also in the offing is a paper on the new electron beam furnace used in the purification of columbium and tantalum. A description of the Strategic-Udy process is planned, too.

An all-day session on gold is another feature of the meeting. Internationally-known figures in mining, banking, and finance will be on hand to discuss the economic and monetary aspects of gold at domestic and international levels.

Wives of delegates who attend the Conference are in for special attention, with a shopping tour, luncheon, city tour, and visit to the city's art museum among the plans.

The Oregon section, AIME, is the 1960 host for the round-robin conference, jointly sponsored by the Columbia, North Pacific, and Oregon sections.

Navy Metallurgy Research to be Topic At 1960 Annual Meeting

The AIME Annual Meeting in 1960 will initiate a series of Defense Department programs in metallurgy. The Institute of Metals Division of The Metallurgical Society will host a forum on Metallurgy in the Navy —Requirements, Application, and Research, the first of the service programs. Future participation by the Army is planned for next year's Fall Meeting, while it is anticipated that the Air Force will be represented at the 1961 Annual Meeting.

Feb. 15th, the opening day of technical sessions has been devoted to the Navy all-day forum.

Registration day is Feb. 14th, with technical sessions being held at the Sheraton-Atlantic Hotel (until recently the Sheraton-McAlpin on Feb. 15-18.

The Chemistry and Physics of Metals Committee has lined up a session on Diffusion. Several other sessions based on research abstracts are also planned. The IMD Annual Lecture for 1960 will be given by Professor N. F. Mott, F.R.S., Cavendish Professor of Physics, Cambridge University. Time of the Lecture is Wednesday morning, Feb. 17th.

The IMD will also be the joint sponsor of a session on Surface Phenomena. The Basic Science Committee, Minerals Beneficiation Division, Society of Mining Engineers, is cosponsor of the all-day meeting Wednesday, Feb. 17th.

The Extractive Metallurgy Division's Annual Meeting program will feature an International Symposium on the Extractive Metallurgy of Copper, Nickel, and Cobalt. The Hydrometallurgy, Pyrometallurgy, and Electrolytic Processes Committees of the EMD are the Symposium's cosponsors. Fuel-fired smelting, electric smelting, roasting, and the refining of copper, nickel, and cobalt will be among the discussion topics. A total of 14 sessions will be wholly-sponsored by the EMD.

The 1960 Extractive Metallurgy Lecture will be given by Charles R. Kuzell, of Phelps Dodge Corp., the morning of Thursday, Feb. 18th.

The Iron and Steel Division will feature two sessions by the Acid Converter and Basic Oxygen Steel Committee in its portion of the program. Papers will cover new developments in acid bessemer steelmaking . . . resumé of first year's operation at Kaiser Steel . . . endpoint temperature control of the basic oxygen furnace . . . present status of steel specifications met by oxygen steel . . . description of the first North American O_2 steelmaking operation using cupola iron . . . summary of the latest developments in the L-D process outside North America . . . the recent development of the basic bessemer processes of steelmaking and the LD-AC process . . . and the latest developments in the Kaldo oxygen steelmaking process.

The Physical Chemistry of Steelmaking Committee is planning two sessions on solidification. Fundamental studies of solubility, equilibriums, and kinetics, as well as the practical application of such fundamental information are planned.

The ISD Lecture will be given by Dr. Robert F. Mehl, Carnegie Institute of Technology, on Tuesday morning, Feb. 16th. Following it will come the Third Annual ISD fellowship luncheon.

Co-ordinator of the IMD Annual Meeting sessions is Program Chairman J. H. Jackson, Battelle Memorial Institute. W. W. Stevens, The Carborundum Co., is Program Chairman of the EMD portion of the meeting. C. W. Sherman, Jones & Laughlin Steel Corp., is the ISD program chairman.

New York Physical Metallurgists Visit Titanium Pigment Facility

The Oct. 21st meeting of the Physical Metallurgy Group, New York section, featured a trip to the Titanium div., National Lead Co., at South Amboy, N. J.

Although one of the world's largest titanium pigment producing centers, the plant's extensive research laboratories captured the groups primary interest.

The Single Crystal Laboratory was one such feature. Originally set up to study the properties of single crystals of titanium compounds, the laboratory has become a producing unit in which the flame fusion process is used to grow crystals of strontium titanate. Since these crystals bear a strong resemblance to diamonds in their diffraction index (although much softer), they are marketed as gems and also as optical components for infrared transmission.

A demonstration of arc furnace smelting of titaniferous ore also aroused considerable interest in the 42 plant guests. The experimental work is part of a program designed to make use of the iron found in the ilmenite concentrates used to produce titanium pigments. Most of the plant's ilmentite supply comes from the McIntyre mine in northern New York state, and contains 45 pct TiO_2 and 35 pct Fe. Digesting the ilmentite in sulfuric acid produces considerable quantities of ferrous sulfate which must be taken out to sea and dumped. By arc smelting 2.4 tons of ilmenite concentrate with 0.24 tons of coke and 0.15 tons of fluxes, some 1.4 tons of titaniferous slag and 0.7 tons of iron are produced. After desulfurization, the iron could be used commercially, and the slag, containing 1 ton of TiO_2, could be treated by dissolution in sulfuric acid. This process is similar to that employed by the Quebec Iron and Titanium Co.

Also seen was the plant's ram reactor, a continuous process for reducing chlorides of refractory metals. The process, perfected on reducing zirconium tetrachloride in a 6-in. ram reactor, is reportedly ready to be put into large-scale development when market developments warrant. Visitors were informed that an 8-in. ram would have an output equivalent to four batch-type reactors. The process was described in an article by W. W. Dunham, Jr., and R. D. Toomey in the July 1959 issue of JOURNAL OF METALS.

Also seen were flowsheets for titanium making processes, including an electrowinning process making use of a basket-like cathode. The latter technique, developed in the South Amboy laboratories, has been used on an experimental basis for refining titanium scrap and in zirconium extraction.

Following the laboratory tours, the group gathered at the plant conference room to hear an official welcome from R. W. Brickenkamp, manager of research. Next came a movie which traced the story of titanium pigment from start to finish. *The Ninth Element* noted that although not ninth in the periodic table titanium is ninth in total usage. At this point the meeting adjourned to the company cafeteria for dinner. The meal afforded the first opportunity to exchange greetings between participants in the jam-packed afternoon-evening meeting.

Reconvening in the conference room, the physical metallurgists heard a talk by J. E. Kunzler, Bell Telephone Laboratories. Dr. Kunzler outlined *Some Recent Advances in Metallurgical Research at Low Temperatures*. Beginning with a review of low-temperature phenomena and techniques, he moved to a discussion of electrical resistance in nearly pure metals.

ISD Acid Converter and Basic Oxygen Men Visit Algoma Plant

Algoma Steel Corp. served as host to the Iron and Steel Division's Acid Converter and Basic Oxygen Committee off-the-record meeting at Sault Ste. Marie, Ontario, Canada Oct. 14th. A total of 60 committee members and guests were on hand for the plant tour.

There they witnessed 100-ton heats made in an average tap-to-tap time of 66 min, with oxygen flow averaging 27 min per heat.

During the technical session of the meeting, the status of new oxygen steelmaking plants at the Cleveland works of Jones & Laughlin Steel Corp., and the Chicago plant of Acme Steel Corp., were reviewed. Recent European developments in oxygen steelmaking were also discussed. Problems common to the process include charging of iron, flux, and scrap; oxygen supply; vessel design; vessel linings; vessel operations; and refining practices. The technical session concluded with a review of current practices in the acid bessemer steelmaking process.

Windup of the all-day meeting was a dinner at the Windsor Hotel, courtesy of Algoma Steel. Chairman of the meeting was A.B. Wilder, chief metallurgist, National Tube div., U. S. Steel Corp.

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TUESDAY, JANUARY 19, 1960

6:00 pm-9:00 pm Registration
Crystal Ballroom Lobby

WEDNESDAY MORNING JANUARY 20, 1960

8:00 am Registration
Crystal Ballroom Lobby

9:15 am-12:00 noon Crystal Ballroom

Problems of Processing to Semi-Finished Products

Chairmen:

Dr. C. R. Taylor, Supervising Research Metallurgist, Armco Steel Corp., Middletown, Ohio and J. McCarthy, Assistant Superintendent, Blooming, Hot Strip and Rolling Mills Dept., Jones & Laughlin Steel Corp., Aliquippa, Pa.

Hot Machine Scarfing of Semi-Finished Carbon Steels, L. J. Trilli, Supervising Metallurgist, Control Section, Open Hearth and Blooming Mill Division, Metallurgical Dept., Inland Steel Co., East Chicago, Ind.

Selection of Ingot and Slab Sizes for the Modern Strip Mill, W. W. Brown, Process Metallurgist, United States Steel Corp., Pittsburgh, Pa.

Fundamental Aspects of Scale on Hot Rolled Strip, S. Garber, Head of Laboratories, Mechanical Working Division, British Iron and Steel Research Association, Sheffield, England.

12:00 Luncheon (Included with registration fee)

Speaker: Thomas Collins, Assistant Managing Editor, "Chicago Daily News"

Subject: "How Business and Professional Men Must Prepare for Retirement"

WEDNESDAY AFTERNOON JANUARY 20, 1960

2:00 pm-5:00 pm Crystal Ballroom

Flat Rolled Products

Chairmen:

A. F. Forrest, Assistant Chief Metallurgist, Republic Steel Corp., Cleveland, Ohio and P. J. Ladomer, Manager, Wide Strip Division, Great Lakes Steel Co., Ecorse, Detroit, Mich.

Temper Rolling and its Effect on Stretcher Strain Sensitivity, E. J. Paliwoda, Senior Research Engineer, Steel Processing, and I. I. Bessen, Research Supervisor, Physical Metallurgy, Research Division, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Unitized Automobiles, Carl Cenzer, Executive Body Engineer, American Motors Corp., Detroit, Mich.

Processing and Properties of Magnetic Materials. Papers by R. H. Trapp, Senior Engineer, Westinghouse Electric Corp. and P. H. Estes, Magnetic Materials Applications Engineer, General Electric Co.

5:00 pm-6:00 pm Cocktail Hour
Park View Room

GENERAL INFORMATION

Registration—Registration fee including the cost of lunch and a copy of Proceedings—$13.00 for members of AIME, $15.00 for non-members.

Advance registration may be made by sending a check to *Philip H. Smith, LaSalle Steel Co., P. O. Box 6800A, Chicago 80, Illinois.*

Del Prado Hotel—Located at Hyde Park Blvd. at 53rd Street. All Illinois Central and "Big Four" trains stop at 63rd Street, convenient to hotel.

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PERSONALS

(Continued from page 784)

the metallurgy dept., Montana School of Mines. Dr. Griffiths comes to Montana from Vancouver, British Columbia, where he was a research associate in the dept. of metallurgy, University of British Columbia.

Merritt A. Williamson, dean of the College of Engineering and Architecture, Pennsylvania State University, was recently designated "Man of the Month." The title was conferred by a University magazine called *Industrial Science and Engineering.*

Charles B. Hausen has been named to fill the newly-created position of corrosion engineer at the Bunker Hill Co. He will be responsible for the initiation, maintenance, and evaluation of all corrosion protection programs for Bunker Hill.

John L. Everhart is now affiliated with International Nickel Co. Previously, he was a technical editor with the Reinhold Publishing Corp.

Set Time, Place for 14th New England Regional Conference

Time and place have now been decided on for the 14th New England Regional Conference. May 26-27, 1960 is the time; the Hotel Statler in Boston, the place.

New Developments in Metalworking will be the theme of the 1960 Conference. Tentative scheduling calls for three technical sessions plus a plant tour in the Boston area. Session topics will cover the areas of High-Speed Forming, Extrusion, and Special Forming Processes. Richard Davis, Arthur D. Little, Inc., has agreed to give the *theory talk* in the High-Speed Forming session. John Rinehart, Colorado School of Mines, will give a talk on Explosive Forming during the session.

As in last May's Conference, each technical session will be prefaced by a review of the theory involved. The remainder of the time will be given over to papers and panel discussions covering the practical aspects of the subject under study.

The 1960 Conference will also feature educational exhibits. Space is being alloted for graphic material designed to illustrate the talks. No sales exhibits will be permitted, it is emphasized.

The Connecticut, Hudson-Mohawk, and Boston sections of AIME will again be the Conference's sponsors. Meeting organizers include J. P. Lynch, Jr., Chairman; P. J. Clem, Secretary; and R. E. Keith, Publicity Chairman.

TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME

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Meeting of S. Ohio Section, NOHC, Draws Record 215

A record 215 atended the 23rd Annual Conference of the Southern Ohio section, National Open Hearth Steel Committee, on Oct. 16th. The Deshler-Hilton Hotel in Columbus was the site of the technical conference.

First speaker was A. H. Osborne, Armco International Corp., Middletown, Ohio, who described *The Steel Industry of Japan*, sixth in world's steel production. In Japan, labor is plentiful, as many as seven men may be assigned to a furnace. Use of oxygen for decarburization in open-hearth furnaces has been greatly expanded, with comparable increases in production rates. The speaker summarized conditions of employment, wage scales, and status of labor unions in Japan.

R. L. Sigl, combustion engineer, Detroit Steel Corp., Portsmouth, Ohio, described *Checker and Flue Maintenance During Extended Furnace* Campaigns. Experience has been obtained with four 250-ton furnaces operating since February 1954, and one 275-ton furnace added in February 1957. Of fundamental importance is a good soot blowing system.

Basic Capped Checkers were installed at Armco Steel Corp., Middletown, Ohio, in order to justify higher firing rates, which in turn increased tonnage of steel produced. L. Yoder, general foreman of the Masonry Dept., described the operation.

Operating Results With Ladle Additive Feeders were described by Thomas Murray of Armco Steel Corp., Ashland, Kentucky. Previously, 50-lb. bags were manually thrown into the ladle—a practice recognized as laborious, expensive, and unsafe. Ladle additives are now fed through a chute from feeder hoppers at a controlled rate. These advantages have been realized: increased percentage of alloy recovery, elimination of mechanical losses of alloys, greater uniformity of steel produced, elimination of hot laborious work, and improved safety.

The morning session concluded with three papers on *Heat Temperature Control—Discussion of the Expendable Immersion Thermocouple* describing work at Armco Steel Corp., Middletown, Ohio (presented by J. R. McDermott); at Acme-Newport Steel Co., Newport, Ky. (presented by R. Kuhni); and at Detroit Steel Corp., Portsmouth, Ohio (presented by Kenneth Ott). Serving as chairmen of the morning session were R. K. Thornberry, superintendent of steel melting, Acme-Newport Steel Co., and O. V. Ireland, supervising metallurgist, Armco Steel Corp., Middletown.

Lead-off paper for the afternoon session was given by C. J. Petry who described Acme Steel Co.'s new *Oxygen Steelmaking Process*. Since Acme found it increasingly difficult to obtain semi-finished steel as their raw material, management decided to produce steel themselves at Riverdale, Ill., using the oxygen steelmaking process. In addition to constructing two oxygen steel furnaces, a unique feature was planned—hot metal from two cupolas. The results described by Mr. Petry were based on 120 heats—three weeks of operation—prior to the start of the steel strike.

J. N. Albaugh, superintendent, steel works, Jones & Laughlin Steel Corp., described the *Oxygen Steelmaking Process* at the Aliquippa, Pa., plant. Average heat size is considerably above the rated capacity; life of oxygen lances is greater than other plants have experienced; steels produced have consistently had low sulfur, phosphorus, and nitrogen contents.

A. L. Hodge of Linde Co., in his paper on *Oxygen in Open Hearth Furnaces*, sounded an optimistic note for its future. The basic difference between open hearth and oxygen steel furnaces is that the former have end burners; making extra heat available.

The technical session concluded with a *Progress Report on Basic Roofs* in which the following participated: McBeth Sample, general foreman, # 2 open hearth, Armco Steel Corp., Middletown; R. L. Lewry, open hearth superintendent, Detroit Steel Corp.; Portsmouth, Ohio; and R. E. Over, vice president, M. H. Detrick Co., Chicago.

Presiding as Chairmen of the session were R. L. Lewry of Detroit Steel and Thomas Murray of Armco Steel Corp., Ashland, Ky.

Highlight of the day's activity was the Fellowship Dinner. D. R. Loughrey, Chairman of the National Open Hearth Steel Committee, and coordinator of steelmaking, Jones & Laughlin Steel Corp., served as Toastmaster. Principal address was given by Floyd Faust, Pastor of the Broad Street Christian Church, and founder of Alcoholics Anonymous. In his inspirational message, *Fit for Freedom*, Dr. Faust urged strict family discipline so that our children will be hardened to the difficulties of life as they mature. Otherwise, the future of our civilization is in doubt.

Final activity for many attending the 23rd Conference was the Ohio State-Purdue football game on Saturday, Oct. 17. This day also marked the Fall meeting of the Executive Board of the National Open Hearth Steel Committee. There it was announced that the Southern Ohio Section was contributing $150 to the United Engineering Center.

Responsible for the highly-successful meeting were the Section officers—William W. Bergmann, Chairman, and G. E. Brehm, Secretary. Mr. Bergmann is superintendent, # 1 open hearth dept., Armco Steel Corp., Middletown; Mr. Brehm is steel plant statistician, Armco Steel Corp., Middletown.

Plan Four Sessions at Columbium Symposium Next June

A four-part program has been planned for the Columbium Metallurgy Symposium, to be held at Lake George, N. Y., June 9-10, 1960. Each of the four topics will constitute one session during the two-day meeting.

Mechanical properties of columbium, as influenced by alloying, environment, and treatment, will be one of the topics. Under discussion will be tensile, creeping-rupture, impact, fatigue strengths, and so on. Fabrication, including the conversion, shaping, and joining of columbium and its alloys, is a second topic.

Corrosion and oxidation—chemical reactions with liquid and gaseous environments, including effects of coatings—is also on the agenda. And general physical metallurgy of the metal-phase equilibria, kinetics, textures, radiation damage, and related problems is to be the subject of the fourth and final session.

R. E. Keith, publicity chairman of the Hudson-Mohawk section committee sponsoring the Symposium, announces that additional papers in all sessions are welcomed, subject to approval of the Symposium Committee. Abstracts should be received by Feb. 1, 1960, with final drafts of papers in by May 1st.

Persons desiring to present papers should contact *Dr. D. L. Douglass, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.*

Maintenance Show Notes Metals Problems

The 11th Plant Maintenance and Engineering Conference will feature round-table discussions on the problems of foundries; metal-working and metal-fabricating plants; steel mills; and research, development, and pilot plants.

The Conference will be held at Convention Hall, Philadelphia, Jan. 25-27, 1960, as part of the overall Plant Engineering and Maintenance Show running from Jan. 25-28.

For more information, contact: Clapp & Poliak, Inc., 341 Madison Ave., New York 17.

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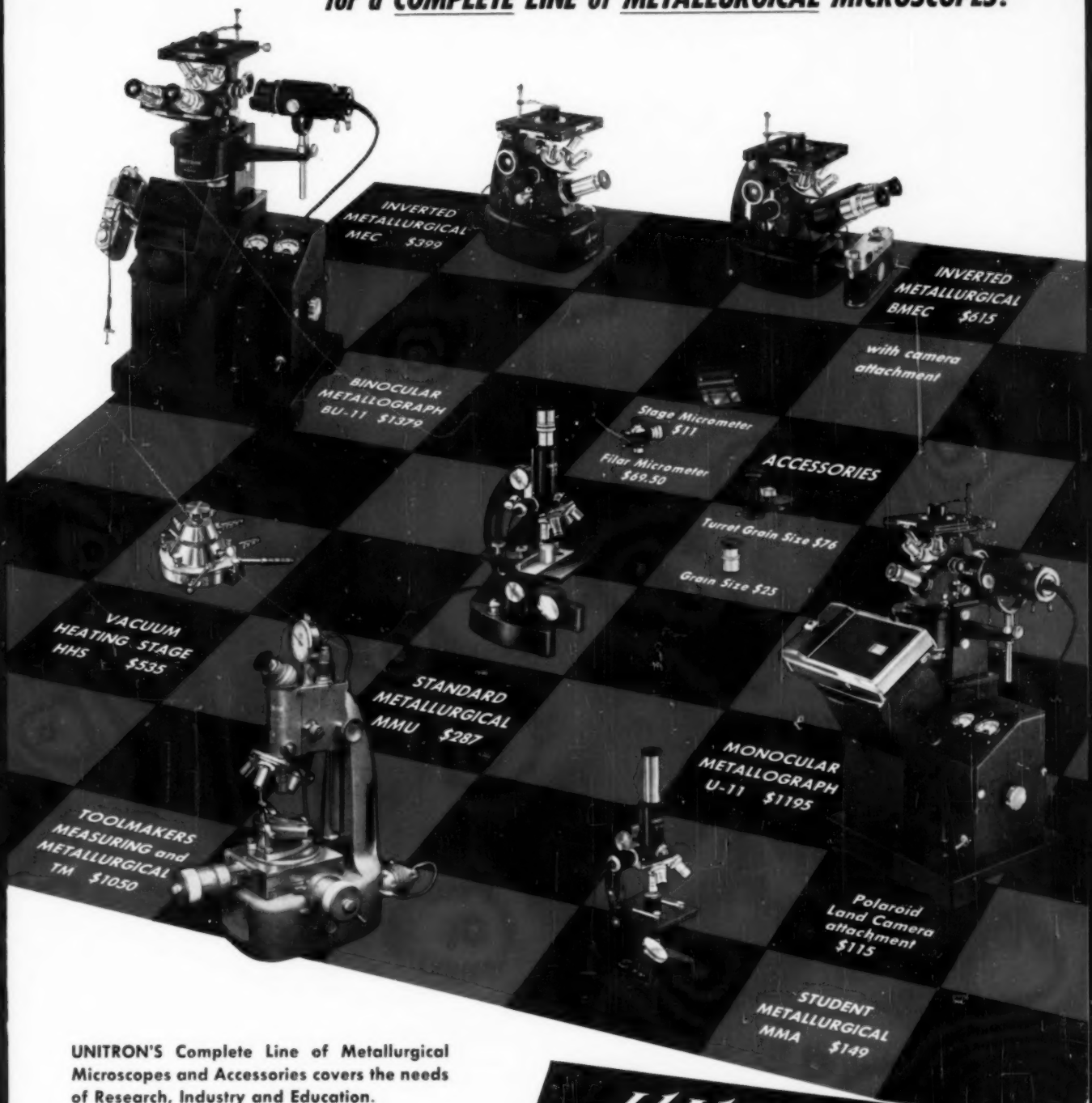

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AROUND THE SECTIONS

Arizona section has topped its quota of $7100 with a total of $7825 pledged as of Oct. 10th. **Morenci** subsection is largely responsible for the feat, contributing $890 with its 45 pledges—more than one-fourth of all pledges received by the Section. A tip of the hat to drive Chairman W. C. Couger. Keep up the good work!

Next big event on the Arizona section's calendar is its Annual Meeting at the Pioneer Hotel in Tucson Dec. 7th.

Chicago section heard Mr. W. E. Scanlan of the Mississippi Valley Association speak on the *Port of Chicago and the Calumet Harbor District* at its Oct. 7th meeting. In the course of the talk, Mr. Scanlan charted the flow of world market goods in the mid-continent waterways area.

The Section's next meeting is Dec. 10th. The meeting has been designated Students Night, and Dr. R. M. Brick, director of research, Continental Can Co., will address the gathering on *Present and Future Metallurgy in the Can Industry.*

Southern California section's Nov. 12th meeting featured Derek Walton, senior research engineer, Solid State Group of Convair Physics section. Dr. Derek spoke on *Mechanisms of Friction and Wear.*

Buffalo section, NOHC, held its Tenth Annual Fall Meeting at the Royal Connaught Hotel, Hamilton, Ontario, Canada, on Nov. 10th. The day started with a tour of the oxygen steel producing facilities of the Dominion Foundries & Steel Ltd. The afternoon technical sessions followed through with a discussion of the similarities in the open hearth-oxygen lancing vs oxygen converter methods of steelmaking. Rounding out the day was a cocktail hour and banquet.

Utah section's guest speaker for its Sept. 17th meeting was Mr. Robert G. Bateman, section supervisor of Materials and Process Laboratory, Marquardt Aircraft Corp. Material requirements came under discussion in his talk on *Metals in Ramjet Engines for the Space Age.* The Salt Lake City meeting also featured a short film on missile launching and testing.

Cleveland section will hold a National Officers and Ladies Night Jan. 21st. AIME President-Elect Joseph Gillson will be on hand to address the gathering. Warren Guthrie, chairman of the Department of Speech, Western Reserve University, will offer a talk on *People Who Need Talking To.* Meeting place, as usual, will be The Cleveland Engineering and Scientific Center, 3100 Chester Ave.

San Francisco section's Oct. 14th meeting was attended by 66 members and guests. Featured speaker was Robert H. Raring, of Western-Knapp Engineering Co. Mr. Raring spoke on *Gold Plants of the Future —Lessons From Uranium.* In the talk he noted that the race for leadership in world uranium production has done more for perfecting American gold mining techniques than gold producers have ever accomplished. Similarities in ore treatments of the two metals gave rise to these advances, he explained.

St. Louis section heard Schrade F. Radtke, director of research, American Zinc Institute, speak on *An International Research Program in Lead and Zinc* at its Nov. 13th meeting. In his talk Dr. Radtke outlined some of the Institute's research and development programs on current and potential uses of lead and zinc. An illustrative film accompanied the business-dinner meeting talk.

Name Speaker for Los Angeles Metals and Minerals Conf.

Albert C. Hibbs, chief of the Division of Space Sciences at Jet Propulsion Laboratories, California Institute of Technology, will be the banquet speaker at the Southwest Metals & Minerals Conference, Apr. 21-22, 1960.

Dr. Hibbs, who directs the development of instruments for space probes, will speak on the general theme of the Conference, *Metals and Minerals for the Space Age.*

Beryllium metallurgy . . . energy sources for fuels . . . industrial minerals . . . materials for the space age . . . special minerals for ground installations . . . a rock products symposium . . . a symposium on boron . . . a mining session . . . and related topics are on the agenda. In addition to the two days of technical sessions, field trips are scheduled for Saturday, April 23rd.

Site of the Conference is the Ambassador Hotel, Los Angeles. The Rock Products Assn. of Southern California has this year joined the Southern California, Reno, and San Francisco sections of AIME in sponsoring the event.

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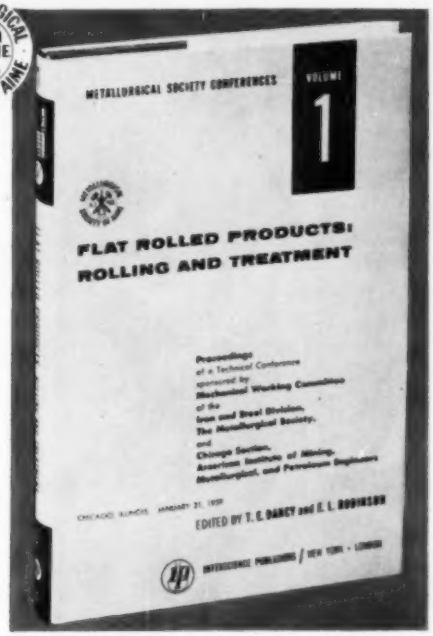

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148 pages, illustrated $3.75

2 Reactive Metals

Sponsored by the Niagara Frontier Section in cooperation with The Metallurgical Society of AIME. Buffalo, May 27-29, 1958. Edited by W. R. CLOUGH

In press

3 Quality Requirements of Super-Duty Steels

Sponsored by the Physical Chemistry of Steelmaking Committee of the Iron and Steel Division, Institute of Metals Division, The Metallurgical Society and the Pittsburgh Section of AIME. Pittsburgh, May 5-6, 1958. Edited by R. W. LINDSAY

In press

4 Physical Metallurgy of Stress Corrosion Fracture

Sponsored by the Corrosion-Resistant Metals Committee of the Institute of Metals Division, The Metallurgical Society and the Pittsburgh Section of AIME. Pittsburgh, April 2-3, 1959. Edited by T. N. RHODIN

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Also to be published under the sponsorship of The Metallurgical Society of AIME

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San Francisco, February 16-17, 1959. Edited by W. D. WILKINSON, Argonne National Laboratory

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Physical Chemistry of Process Metallurgy

Pittsburgh, April 27-30, 1959. Edited by G. R. ST. PIERRE

Properties of Elemental and Compound Semiconductors

Boston, August 31-September 2, 1959. Edited by H. C. GATOS

Refractory Metals

Detroit, May 25-26, 1960

Response of Materials to High Velocity Deformation

Estes Park, Colorado, July 11-12, 1960

Other volumes to be announced

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Eastern Section of NOHC Hosts Technical Meeting

The assertion: "I'm going to try it" echoed at the meeting of the Eastern Section, National Open Hearth Steel Committee, AIME, attests to the know-how on pouring pit practices and basic open-hearth roofs gained by the nearly 300 registrants.

The all-day technique-swapping meet convened at 9:30 am in the ballroom of the Warwick Hotel, Philadelphia.

First on the program introduced by Chairman George S. Baldwin was an announcement of the prize-winning papers in the Section's annual competition. Donald E. Grimme and Donald K. Matthews, both of Lukens Steel Co., copped first prize with a paper on *The Tiger Top at Lukens.* Second prize went to Jame L. Garrity, Bethlehem Steel Co., for a discussion of *Furnace End Construction.*

In keeping with the Section's policy of hearing the first prize paper, Mr. Grime read his paper describing the design of an umbrella used in the pouring of hot top molds at Lukens. The name of the process derives from Magnus Tigerschiold, of Sweden, its developer.

Next on the program was a panel discussion on Pouring Pit Practices, ably moderated by J. Gardner Blythe, John A. Roebling's Sons div., Colorado Fuel & Iron Corp.

Frank Higgins touched off a lively discussion with an account of *Defects in Top Cast Ingots,* as encountered at Phoenix Iron & Steel Co. W. Maier, of the Fairless works, U. S. Steel Corp., next related the *Use of Bells in Ladle Preparation.* William Webb also elicited comments from the audience with a comparison of *Bottom Pouring vs Top Pouring.* He spoke from experiences at the Claymont, Del., plant of C. F. & I., one of the few still using bottom pouring.

C. R. Beamesderfer next alluded to *Pouring Practice at Lukens. Pouring Ingots With Double Nozzles* was the topic of discussion for R. Zweier, of the Sparrow Point plant of Bethlehem Steel Co. R. G. Waite talked about the elimination of gas defects in a description of *Ladle Drying in a Steel Foundry.* Mr. Waite is with General Steel Casting Corp. J. B. Kopec, John A. Roebling's Sons div., C. F. & I. Corp., also prompted comment with reported economies through a centralized mold discard authority. *Mold Scrapping Program* was the title of his talk. A. P. Smith culminated the panel discussion with a notation of *Actual Pouring Temperatures at Bethlehem Steel.*

After a break for lunch, the ever-growing group strained forward to hear Keith Bartels and H. A. Parker discuss burn-out patterns of basic open-hearth roofs at the Fairless works, U. S. Steel Corp. Mr. Bartels explained the sprung arch furnaces' construction, while Mr. Parker emphasized the importance of balancing the furnace with the fuel in basic brick furnace operation.

M. K. Morris, Bethlehem Steel Co., moderated ensuing discussion of the Fairless operation.

The last portion of the technical meeting was moderated by Keith Bartels. He channeled the hot and heavy questioning brought forth from steel men as they listened, visibly impressed, by Edwin Richards' explanation of the *Cupola-Oxygen Converter Installation at Acme Steel Co.* Mr. Richards, director of steel production at Acme, stood in for fellow worker C. J. Petry in reading the latter's paper.

D. L. McBride, director of metallurgical process development for U. S. Steel Corp., was the last speaker of the technical session. In his talk on the *Latest Developments in European Steelmaking Practices,* Dr. McBride traced the historical stages of steel processing in the UK, France, Belgium, and other countries.

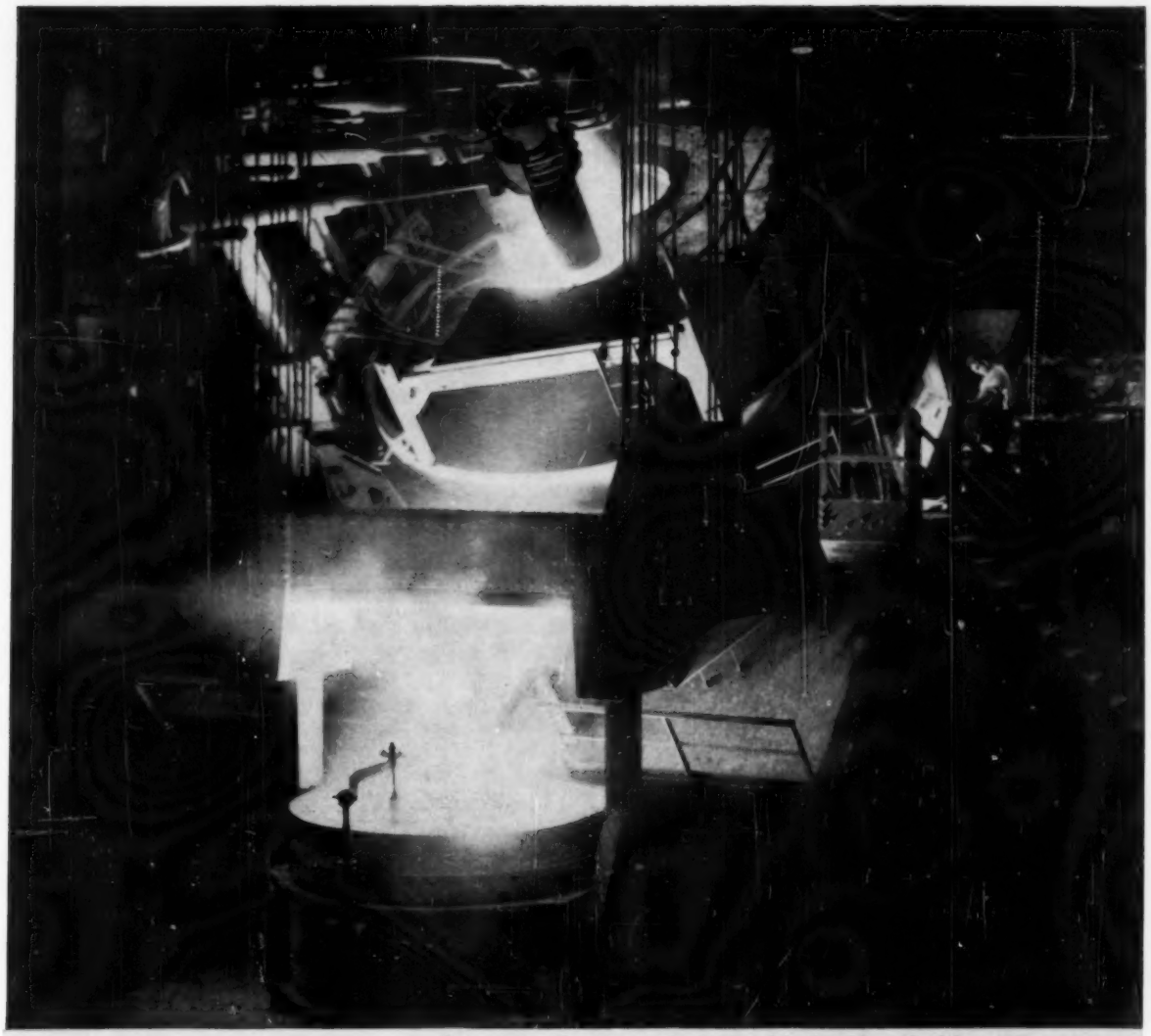
There was a brief respite and time to renew old acquaintances and form new ones before the 6:00 pm cocktail hour, courtesy of the Suppliers' Committee. Fully 201 of the 298 registrants stayed for the 7 o'clock Fellowship Dinner. And fellowship it was with plenty of song thrown in. Competing with the professional abilities of an accordionist, barbershop quartet, and female singer, the impromptu renditions by members and guests added a spirit of good will to the dinner. Highlight of the evening was the presentation of a silver tray in token of C. D. "Pinky" Moore's tenure as 1958 chairman of the Eastern section.

The dinner soon broke up—all too soon for most—but with the promise to "see you next time."

Powder Metallurgists Hear Cobalt Talk

The Powder Metallurgy Group of the New York section, AIME, heard F. R. Morral speak on cobalt powder metallurgy at its Sept. 30th meeting.

Dr. Morral, who is in charge of the Cobalt Information Center at Battelle Memorial Institute, discussed the uses of cobalt powder and its availability and purity. A French film on the *Allotropic Transformation of Cobalt* accompanied the talk; it illustrated cobalt's transmission effects on heating and cooling through 800°F .



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Vernon W. Jones Scholarship Awarded

Winner of the newly-established Vernon W. Jones Scholarship Award for 1959-1960 is James E. Battles, senior metallurgy student at the University of Alabama. The scholarship award was instituted this year in honor of Mr. Jones, immediate past-chairman of the National Open Hearth Steel Committee. The Award carries a $1000 stipend.

Mr. Battles was selected from among 18 junior-year metallurgy student applicants. Now starting his senior year at Alabama, Mr. Battles hopes to pursue graduate work in metallurgy. His receipt of the scholarship marks a career begun as a laborer in a structural steel mill where he was instilled with the "why" of steelmaking that prompted him to return to school after a long absence in order to study metallurgy.

Graduating from high school in 1948, he went to work in the structural mill of the Houston, Tex., plant of Armco Steel Corp. Then came third helper and second helper duties in the open hearth shop. A four year stint in the Air Force begun in 1950 took him away from the Sheffield div. When he was discharged he returned to the Houston plant, this time combining a full-time job with marriage and night school. When the University of Houston dropped its metallurgy curriculum, he switched to Alabama, taking a leave of absence from Armco Steel to complete his schooling. The 29 year-old student has two children: a boy six, and a girl four.

The Award was made possible through the contributions of Jules H. Reichart, president, Sticker Industrial Supply Corp., Cleveland; and A. H. Sommer, director, Keystone Steel & Wire Co., Peoria, Ill. The National Open Hearth Steel Committee hopes that additional contributions will perpetuate the scholarship in Mr. Jones' honor. Dr. G. R. Fitterer, Dean of the School of Engineering, University of Pittsburgh, served as chairman of the committee that performed the monumental task of contacting the many colleges where metallurgy is taught, and then selecting the single individual best qualified. Dr. Fitterer is also chairman of Leo F. Reinartz AIME-NOHC Scholarship Award Committee.

AAAS Meets in Chicago Dec. 28-29

The American Association for the Advancement of Science will meet Dec. 28-29 at the Hotel Morrison, Chicago.

Theme of the engineering portion of the program is the National and International Aspects of Systems of Units. Operation SCUDS is its objective: *S*implification, *C*larification, *U*nification, *D*ecimalization, and *S*tandardization.

Part one of the program, The Confusion of Chaos in Units, should be of particular interest to metallurgists and others. Walker L. Cisler, president of the American Society of Mechanical Engineers, will speak on the *International Viewpoint of an American Engineer on Units*. G. F. Hussey, Jr., managing director, American Standards Association, will pose the question: *Should American Industry Convert to the Metric System?—Summary of Views Recently Expressed by Industry*.

Tuesday afternoon, Dec. 29th, will witness part four of the program, The Look to the Future. Speakers include A. H. Hughes, deputy chairman, British Association Metric Committee, London, with a *Progress Report on the Changeover Problems for Great Britain*. A. V. Astin, Director, National Bureau of Standards, will then relate the *Status of NBS Study-Project on Ways and Means to Accelerate Metric Changeover in the USA*.

McGough Receives NOHC Sponsored Reinartz Scholarship

Thomas H. McGough has been named to receive the L. F. Reinartz Scholarship Award for 1959-1960. The award, sponsored by the National Open Hearth Steel Committee of the Iron and Steel Division, AIME, is given an outstanding student who elects to study metallurgy at Carnegie Institute of Technology, Mr. Reinartz' alma mater. The scholarship provides a $750 stipend.

Selection of the award winner is made by the Leo F. Reinartz AIME-NOHC Scholarship Award Committee. J. M. Daniels, chairman of admissions at Carnegie Tech notes that Mr. McGough graduated with honors from Saint Justin High School, Pittsburgh, and was an award winner in the Able Youth Scholarship Competition, in addition to being a National Merit Scholarship semi-finalist. "He is the type of boy who will work hard and has the ability to succeed," Mr. Daniels observed. Mr. McGough is currently enrolled in his first semester at Carnegie Tech.

The Leo F. Reinartz NOHC scholarship was first awarded in 1955. It is endowed with a $20,000 fund established by the National Open Hearth Steel Committee to honor Mr. Reinartz, 1954 President of the AIME, for his many years of work with the NOHC. Mr. Reinartz is currently a consultant with the Armco Steel Corp., Middletown, Ohio.

PEORIA PLANT TRIP

GANG'S ALL HERE—Pictured above are the 140 men who toured the Keystone Steel & Wire Co. plant at Peoria, Ill., during the Fall Meeting of the Southwestern section, NOHC, on Oct. 9th. They are standing in front of the featured attraction of the tour—a new 180-ton open hearth furnace. The four men in the foreground are, l to r, A. H. Sommer, L. A. Lambing, C. M. Kay, and L. F. Reinartz, Messrs. Sommer, Lambing, and Reinartz are all former chairmen of the National Open Hearth Steel Committee. Mr. Kay is currently on the executive board of NOHC. Total registration for the meeting was 210.

AIME Participant in Power Conference

The AIME is a co-operating participant in the 22nd annual American Power Conference, destined for the Hotel Sherman, Chicago, Mar. 29-31, 1960.

Representing the AIME will be Howard A. Herder of the Chicago section. Accompanying him will be the 1960 Chicago section Chairman, as yet unelected.

The Illinois Institute of Technology is the principal sponsor of the meeting, which is designed as a forum for discussion of problems in the electric power industry and associated activities. Inquiries concerning the Conference should be sent its Director, *R. A. Budenholzer, Mechanical Engineering Dept., Illinois Institute of Technology, 3300 Federal St., Chicago 16.*

R. V. WILLIAMS

R. V. Williams Gets Niagara Section Tone Medal Award

Reginald V. Williams, president and director of Williams Gold Refining Co., was given the Tone Medal Award of the Niagara Frontier section at the Section's annual meeting on Nov. 18th.

The Award, established in 1956, is granted to a resident of the Niagara Frontier community who has made an outstanding contribution to the science of metallurgy.

The dental profession, in particular, has acknowledged Mr. William's research in precious metals. Perfection of the gold-platinum alloy system used, in wire form, in orthodontics, was his invention. He also introduced high-frequency induction melting to the dental industry, making the first homogeneous precious metal alloys. For his work, the Eighth District Dental Society of the State of New York in 1947 made Mr. Williams the only non-dentist member of the Society.

In 1945, he received an award from the US Navy, Bureau of Ordnance, for research and development of a bi-metal alloy used in proximity fuses. At present, Mr. Wililams is involved in the development of semiconductors and transistor alloys for various electronic manufacturers involved in National Defense.

The Tone Medal Award, instituted in honor of Dr. Frank J. Tone, pioneer industrialist of the community, was presented by William W. Stevens, Chairman of the Niagara Frontier Section.

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MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Nov. 1, 1959, was 32,855, in addition 2,798 Student members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Brytczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Almeter, Frank M., Pomona, Calif.
Anderson, John E., Indianapolis, Ind.
Atkin, Oliver B., Bridgeport, Conn.
Ball, Charles S., Port Talbot, S. Wales
Bishop, Warner B., Cleveland, Ohio
Duncan, Norman E., Cleveland, Ohio
Dunleavy, Joseph G., Columbus, Ohio
Jayaraman, Narayanaswamy, Malleswaram, India
Kennedy, Coleman A., Birmingham, Ala.
Marquez B., J. Miguel, Bolivar, Venezuela
Mount, Lloyd E., Bradford, Pa.
Padilla, Victor E., Golden, Colo.
Paul, Wortley B., Philadelphia, Pa.
Pixton, George E., New Britain, Conn.
Ramage, Bruce H., Grosse Ile, Mich.
Reitsema, Roelof, Delft., Netherlands
Sage, Arthur M., Purley, England
Sailer, Edward N., Bradford, Pa.
Schulze, William G., Fontana, Calif.
Steinherz, Hans A., Newton Highlands, Mass.

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Hoge, Daniel H., Jr., Westwood, N. J.

Junior Members

Johnston, John F., Jr., Rochester, Pa.
Kear, Bernard H., Philadelphia, Pa.
McQuie, George R., Kellogg, Idaho
O'Brien, John E., Wakefield, Mass.
Ofiesh, A. Paul, Wappingers Falls, N. Y.
Patzner, Eugene J., Amesbury, Mass.
Townsend, Franklin M., E. St. Louis, Ill.
Warlimont, Hans, Monroeville, Pa.
Eells, Samuel, Jr., Cleveland, Ohio

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Rose, Robert J., N. Olmsted, Ohio

SPECIAL REINSTATEMENT
Associate Member

De Moraes, G. Soares, Sao Jose Dos Campos, Brazil
Eason, William H., El Paso, Tex.

SPECIAL REINSTATEMENT
Junior Member

Bloodsworth, John O., Rolla, Mo.
Dasgupta, Shyama P., Bethlehem, Pa.
Robles, Esteban O., Iligan City, Philippines

OBITUARIES

Cates, Louis S. (member 1904), chairman of the Phelps Dodge Corp., died Oct. 29th at the age of 77. After receiving a degree in mining engineering from the Massachusetts Institute of Technology in 1902, he began as a timekeeper for the former Boston Consolidated Mining Co., Bingham, Utah.

He was president of Phelps Dodge from 1930 to 1947, and chairman since then. Mr. Cates is noted for being the first engineer to use the undercut block caving method of copper mining on a large scale. The mining engineer was 1946 President of AIME. In 1956, he was awarded the AIME Legion of Honor.

NECROLOGY

Date Elected	Name	Date of Death
1904	Cates, Louis S. (Legion of Honor)	Oct. 29, 1959
1932	Bush, John M. (Senior Member)	July 4, 1959
1935	Hobrock, Raymond H.	Sept. 10, 1959
1945	Householder, Leslie W.	July 12, 1959
1942	Kenney, J. R.	Unknown
1923	Livermore, Robert (Senior Member)	Sept. 26, 1959
1953	MacLeod, J. M.	Sept. 7, 1959
1943	Meyer, H. C.	Unknown
1916	Richards, A. H.	Aug. 30, 1959
1943	Rigg, J. A.	Sept. 21, 1959
1945	Sheldon, C. G.	Sept. 16, 1959

Hobrock, Raymond H. (member 1935) died on Sept 10th. Dr. Hobrock was formerly vice president in charge of metallurgical research at Bundy Tubing Co., Birmingham, Mich. Listed in **American Men of Science,** 1955, Dr. Hobrock began his career as a teacher of physics at Purdue University. He also received a fellowship to the Technische Hochschule zu Aachen, Germany.

Richards Adelbert H. (member 1916) died at his Salt Lake City home on Aug. 30th at the age of 81. Mr. Richards was a retired metallurgical engineer of The American Smelting & Refining Co., having left the Company in 1941 after 42 years in their employ.

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Limited to AIME members, or to companies that have at least one AIME member on their staffs. Rates $50 per year per inch.

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Coming Events

Dec. 1-5, Symposium on Structural Changes in Metals and Alloys, co-sponsored by the Indian Institute of Metals and Dept. of Metallurgy, Indian Institute of Science, Bangalore, India.

Dec. 2-3, The Iron and Steel Institute (of the UK) Autumn General Meeting, London.

Dec. 2-4, AIME 17th Electric Furnace Conference, Hotel Cleveland, Cleveland, Ohio.

Dec. 7, AIME Arizona Section, Annual Meeting, Tucson.

Jan. 20, 1960, AIME, Second Conference on Flat Rolled Products, Del Prado Hotel, Chicago.

Jan. 25-29, 1960, Stress Measurement Symposium, sponsored by *Strain Gage Readings*, Arizona State University, Tempe, Ariz.

Jan. 29, 1960, Philadelphia Section, AIME, Annual Meeting featuring election of officers and "Ladies Night."

Feb. 14-18, 1960, AIME Annual Meeting, Hotel McAlpin and Hotel Statler, New York.

Feb. 16-19, 1960, Symposium on Hydrometallurgy, *Wet Processing of Minerals and Industrial Products*, The Australasian Institute of Mining & Metallurgy, Adelaide, Australia.

Mar. 9-10, 1960, Symposium on Processing of Materials for Re-entry Structures, The Mid-West Society of Aircraft Materials and Process Engineers, Dayton, Ohio.

Mar. 15-21, 1960, Third International Conference on Nondestructive Testing, Tokyo, Mar. 15-18; Osaka, Mar. 21.

Mar. 29-31, 1960, 22nd American Power Conference, co-sponsored by AIME, Hotel Sherman, Chicago.

Apr. 3-8, 1960, Sixth Nuclear Engineering and Science Conference, Coliseum, New York.

Apr. 4-6, 1960, AIME 43rd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Palmer House, Chicago.

Apr. 19-22, 1960, International Symposium on the Metallurgy of Plutonium, sponsored by the Societe Francaise de Metallurgie and the French Atomic Energy Commission, Grenoble, France.

Apr. 21-22, 1960, Southwest Metals and Minerals Conference, Ambassador Hotel, Los Angeles, Calif.

Apr. 28-30, 1960, AIME Northwest Regional Conference, Sheraton Hotel, Portland, Ore.

May 25-26, 1960, AIME Symposium on Refractory Metals and Alloys, McGregor Memorial Conference Center, Wayne State University, Detroit.

May 26-27, 1960, The Metallurgical Society, New England Regional Conference on *New Developments in Metalworking*, Statler-Hilton Hotel, Boston.

June 9-10, 1960, AIME Columbium Symposium, sponsored by the Hudson-Mohawk section, Hotel Sagamore, Lake George, N. Y.

June 13-15, 1960, First International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPIF.

July 11-12, 1960, AIME Conference on the Response of Materials to High-Velocity Deformation, Estes Park, Colo.

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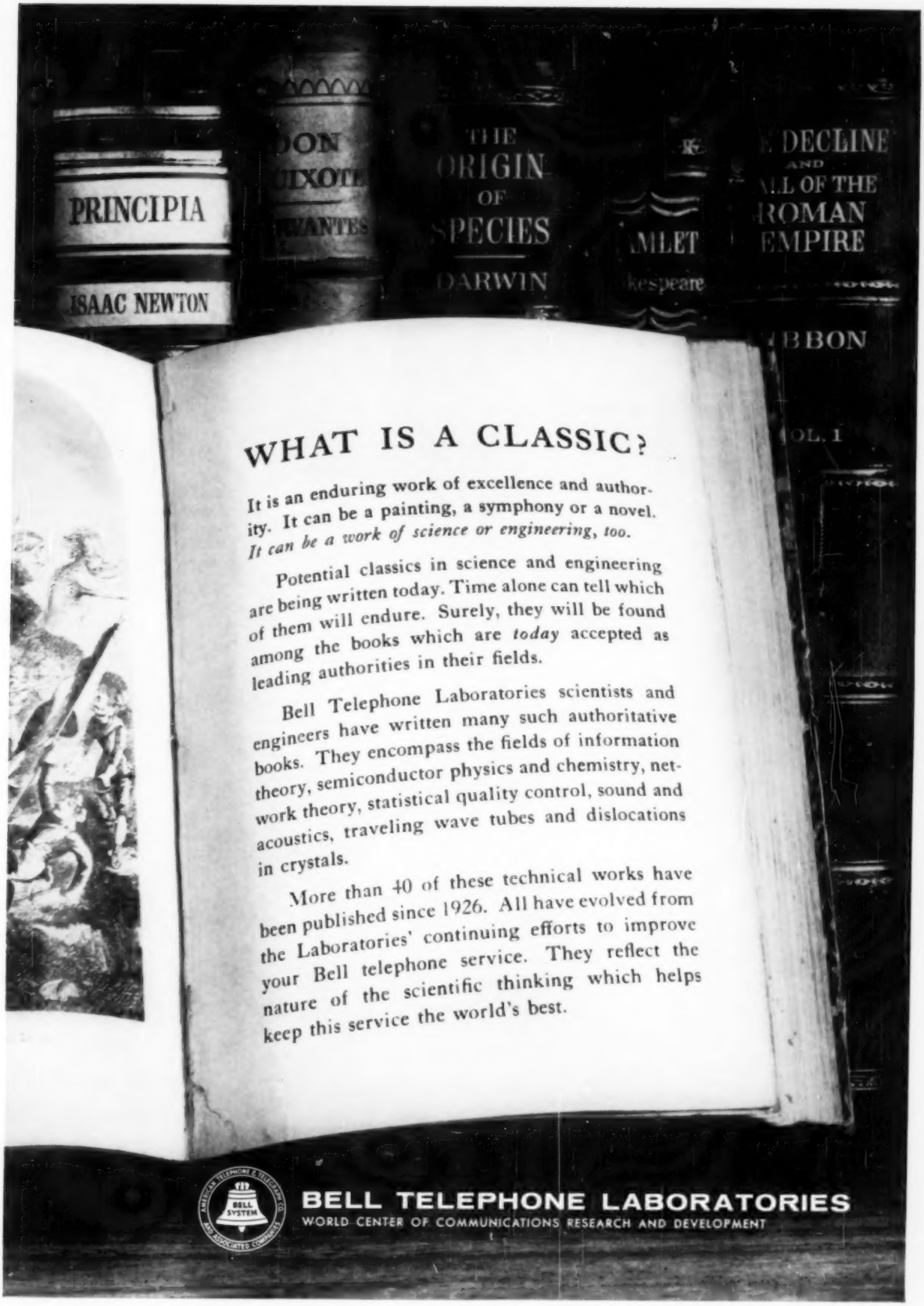

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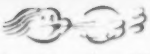

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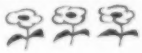

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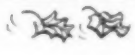

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